



The Blast Furnace and Steel Plant

Published the first of each month by the National Iron and Steel Publishing Co.

Main Office — Thaw Building, 108 Smithfield Street, Pittsburgh.

DISTRICT OFFICES — NEW YORK AND CHICAGO.

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Subscription Price:—In the United States, \$2 per year; Canada, \$2.50; all other countries, \$3.50. Single Copy, 25 cents.
Entered as second-class mail matter at Pittsburgh, Pa., under the Act of Congress, March 3, 1879.

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American Iron and Steel Institute Meeting

More Than Thirteen Hundred Attend Seventeenth General Meeting—Valuable Technical Papers Read—Judge Gary Speaks of Present Labor Situation and Urges Employers to Co-operate.

THE seventeenth general meeting of the American Iron and Steel Institute was held at the Hotel Commodore, New York, May 28.

The technical program contained some very interesting papers. The papers read were as follows:

Industry's Need of Oil—George Otis Smith, Director, United States Geological Survey, Washington, D. C.

Welfare Work in the Steel Industry—C. L. Close, Manager, Bureau of Safety, Sanitation and Welfare, United States Steel Corporation, New York.

Fatigue of Metals Under Repeated Stress—H. F. Moore, Research Professor of Engineering Material, and J. B. Kommers, Research Associate Professor of Engineering Material, University of Illinois, Urbana, Ill.

The Future of Oxygen Enrichment of the Air in Metallurgical Operations—F. G. Cottrell, Bureau of Mines, Washington, D. C.

The Microscope and the Heat-Treatment of Steel—Albert Sauveur, Professor of Metallurgy, Harvard University, Cambridge, Mass.

A Method of Producing Pipeless Rolled Products From Annular Blooms—C. A. Witter, Provident Engineering Company, Philadelphia, Pa.

The Acid Open Hearth Process—B. de Mare, Superintendent, Open Hearth Department, Midvale Steel and Ordnance Company, Philadelphia, Pa.

The paper read by George Otis Smith appears on page 365 of this issue; the paper by H. F. Moore and J. B. Kommers appears on page 368. Professor Albert Sauveur's paper appears on page 373, and the paper by B. de Mare is published on page 318.

More than 1,300 attended the banquet held on Friday evening. Among the speakers were Joseph C. Butler, Jr., Willis L. King, Robert W. Hunt, W. U. Follansbee and Dr. Henry M. Howe.

Judge Gary's annual address dealt chiefly with the present labor situation. "The present so-called labor strikes, involving riot and injury to property and person are instigated as a part of the campaign to disturb and demoralize the economic conditions of the country," Judge Gary asserted. "In other lands very serious results have been accomplished by the same means which have been employed here."

Judge Gary said the "small minority" hope to attract a majority of the people and thus enable them to obtain "one legislative act after another until the constitution shall be undermined and the whole structure destroyed."

"These men," he continued, "have already secured

some legislation which is wrongfully discriminating."

Judge Gary asserted the safe and natural remedy for the "perils" are to be found only in "unity of purpose and effort on the part of the whole crew on board our ship of state, an undivided loyalty to the principles of our constitution and all the laws which are passed in conformity to it."

Speaking of the duties of employers, Gary said they must be "unselfish, reasonable, fair, sincere and honest."

"You should without interruption give evidence of a disposition to conciliate and coöperate," the steel man said.

"Employees must realize that their advancement and contentment depend on the progress and prosperity of their employers; that except for the willing and free investment of capital up to the requirements of business demands, together with the full coöperative assistance on the part of the best talent, enterprise and initiative would languish and disappear and that indifference and idleness would be substituted."

"Agitators who are trying to create trouble between employes and employers are, as a rule, insincere and selfish," Judge Gary averred. "The great mass of employes, if left to decide for themselves, are loyal to the country, to the public interest and their employers," he said.

Judge Gary contended that the honest man who "reads, studies, thinks, works, economizes, saves, persists and uses his best judgment" will succeed in this country.

"If he is neglectful, indolent, profligate and dishonest he will fail. Ordinarily the men who complain because of their poverty or position in life have only themselves to blame."

Opposes Any Discrimination.

Turning to the duties of the public, Judge Gary said, "there must not be any discrimination against or in favor of any group of persons if this country is to retain the position among nations to which it is entitled."

The general public, he asserted, should coöperate with and assist private enterprise.

Discussing the election of the next President, Judge Gary said a man must be selected who is "able, wise and well informed, of unquestioned honesty, morally and intellectually; eminently fair and impartial, frank and sincere, broad minded, deeply sympathetic, courageous, sturdy and well balanced."

Notes on the Acid Open Hearth Process

Discussion of Practice as Carried Out in the Open Hearth
Department of the Nicetown Plant of the Midvale Steel
and Ordnance Company.

By B. DE MARE,

Open Hearth Superintendent, Midvale Steel and Ordnance Company.

IN presenting this paper on the "Acid Open Hearth Process," my aim has been to confine myself to the practice as carried out in the open hearth department of the Nicetown plant of the Midvale Steel & Ordnance Co., and to state the conditions which experience there has shown to be most conducive to the successful manufacture of high grade acid open hearth steel.

Before going any further, permit me to explain what is meant by the expression "high grade" steel.

In a broad sense, any steel, which in a perfectly satisfactory manner serves the purpose for which it is intended, may be considered high grade. In the more narrow sense, however, in which it is here used, it may be defined as a steel which, to be accepted, must pass certain more than ordinarily severe tests, where the margin between success and failure is so narrow and the financial loss by failure so great, that the steel maker is not only justified, but compelled, to leave nothing undone which in any possible way may improve the quality of the steel, regardless of quantity or of any reasonable increase in its cost of manufacture, in order to insure a high percentage of acceptance, when the steel is finally submitted to the test.

The more important products of acid open hearth steel, manufactured by Midvale, are as follows:

1. Armor piercing projectiles.
2. Gun forgings, especially of large caliber.
3. Large or intricate forgings such as marine crank shafts and connecting rods, bucket wheels and pinion shafts for steam turbines, and other forgings in which transverse strength is required.
4. Forgings which require a hard and polished surface without flaw or blemish, such as hardened rolls.
5. Special grades of bar steel.
6. Locomotive and car wheel tires.

The order in which the above classes have been enumerated may be considered as indicating the relative severity of the acceptance tests they have to pass, and therefore, the relative degree of quality required, the armor piercing projectiles requiring the highest quality, with gun forgings a close second, and so on.

The test required for the acceptance of projectiles is as follows: From each lot of 500 projectiles, four are selected to be fired against a face hardened armor plate at a certain velocity and angle of impact, of which two must pass through the plate and remain in effective bursting condition. Should this test be a failure, four more projectiles may be selected and fired, of which three must pass through the plate and remain in effective bursting condition. In the case of 16 inch shells, the cost to the contractor of this second test would amount to about \$20,000. Should it fail, the whole lot of 500 projectiles may be condemned, or the contractor may be permitted to retreat it and re-submit it as a new lot, which would entail an extra expense of approximately \$100,000. It is thus evident that every possible attention must be paid

to the quality of this steel, in order to avoid great financial loss, as well as loss in reputation.

The chief test for acceptance of gun forgings are the tangential test bars taken from the breech and muzzle ends of the rough machined forgings. As specified, these shall be located with their axes in planes perpendicular to the major axis of the forging, and also with their axes perpendicular to the radii, which pass through the middle points of the lengths of the bars, and for larger gun forgings are to be taken, one from the outer, two from the middle, and one from the inner section of wall at each end of the forging. The contractor will be allowed three official tests only. Where the test specimens fail to meet the requirements on the third submission, the piece shall be finally rejected, with certain exceptions.

The minimum physical qualities of nickel steel gun forgings of three-inch caliber and above are as follows:

	T. S. lbs. per sq. in.	E. L. lbs. per sq. in.	Elong. per cent	Contr. per cent
Tubes and liners...	90,000	55,000	18	30
Jackets	90,000	60,000	18	30
Hoops	95,000	65,000	18	30

Other causes for rejection of gun forgings are ghostliness, where careful examination shows any lack of continuity of the metal slag pockets and sand splits, or cavities containing particles of slag, etc., if, in the opinion of the inspector, they are serious enough. Bearing in mind that the present standard 16-inch 50 caliber navy rifle is built up of forgings, made from ingots up to 63-inch octagon in section and 200,000 lbs. in weight, the importance of taking every possible care to avoid defects liable to cause their rejection may be appreciated.

What has been said of gun forgings applies in greater or less degree to the forgings mentioned in Class 3, especially where transverse strength is required, as determined by transverse or tangential test bars.

As regards the fourth class, such as hardened rolls, the difficulty with them is that after having been forged, annealed, machined, hardened, ground and polished, if then a careful inspection should reveal any imperfection in the polished surface, such as a small oxide or slag spot, hardly visible to the naked eye, this would condemn the roll as being unfit for its purpose.

In the remaining two classes, No. 5, special grades of bar steel, and No. 6, locomotive and car wheel tires, we approach the borderland, where the acid and basic open hearths compete, and where, except in a few cases, it is largely a matter of cost, which one is to be preferred, bearing in mind, however, that even in these classes, as far as quality is concerned, the acid product is superior to the basic, and, therefore, should command a higher price.

What is the reason then for the superiority of acid over basic open hearth steel for the classes of steel products just mentioned? That it actually is superior, especially for any forgings depending on transverse test-bars for their acceptance, has been repeatedly proven,

Paper read before seventeenth general meeting of the American Iron and Steel Institute.

not only by our own experience, but by that of many others in this country as well as in England and France. Every attempt for instance, to make heavy ordnance of basic open hearth steel, has from all accounts resulted in nothing but failure.

The reason for this is that the quality of the steel is measured by its freedom from oxides, and that acid open hearth steel is more free from these oxides than basic steel, because acid open hearth slag is more effective than basic slag by its reactions with the steel to de-oxidize it.

Of course, there is no open hearth steel, acid or basic, absolutely free from oxides, nor is there any other steel, no matter by what process made, which under the microscope does not show oxide spots.

Therefore, oxidation is only a matter of degree, and the various processes overlap, so that a badly melted steel, by whatever process produced, may be worse than a well melted steel produced by any of the other processes. Therefore, when the claim is made that acid open hearth steel is better than basic, this holds good only insofar as full advantage has been taken of the fact just mentioned in regard to acid slag, as compared with basic.

The effect on the ingot metal of this difference in the degree of oxidation may be shown by the following facts:

1. The amount of de-oxidizing finals, just sufficient to produce an acid ingot free from blow-holes, is not sufficient to make a basic ingot of similar composition solid, but will leave it decidedly blowey. For instance

tire-ingots, which are sliced in laths into several blocks, and where therefore any lack of solidity in the ingot would be discovered, as the blocks are always carefully inspected just for such a defect, have proven beyond doubt, that basic tire-ingots are much more liable to be blowey than acid, and that it is absolutely necessary to add more de-oxidizing finals to basic than to acid heats, in order to make basic ingots as free from blow holes as the acid ones. This proves that basic steel is more oxidized than acid steel. Consequently, the greater amount of finals required for de-oxidizing the basic steel, reacting with the greater amount of oxides in the steel, will produce a greater amount of the non-metallic impurities resulting from this reaction, chiefly silicates of manganese.

2. The ingot crystals of basic steel as shown by tire ingots, as well as by numerous experiments with other grades of steel, are very much larger than those of acid steel, poured under the same condition. For this reason, and also because basic steel is more oxidized than acid, the finely divided oxides, still retained by the crystallizing steel and to a greater or less degree expelled by the growing crystals into the inter-crystalline space, will thus form in the basic ingot a honeycomb of non-metallic impurities much more serious than in the acid ingot. The Ferrite envelope surrounding the ingot grain, which marks the inter-crystalline space as the ingot is cooled down, will also be far more distinct in size and outline in the basic

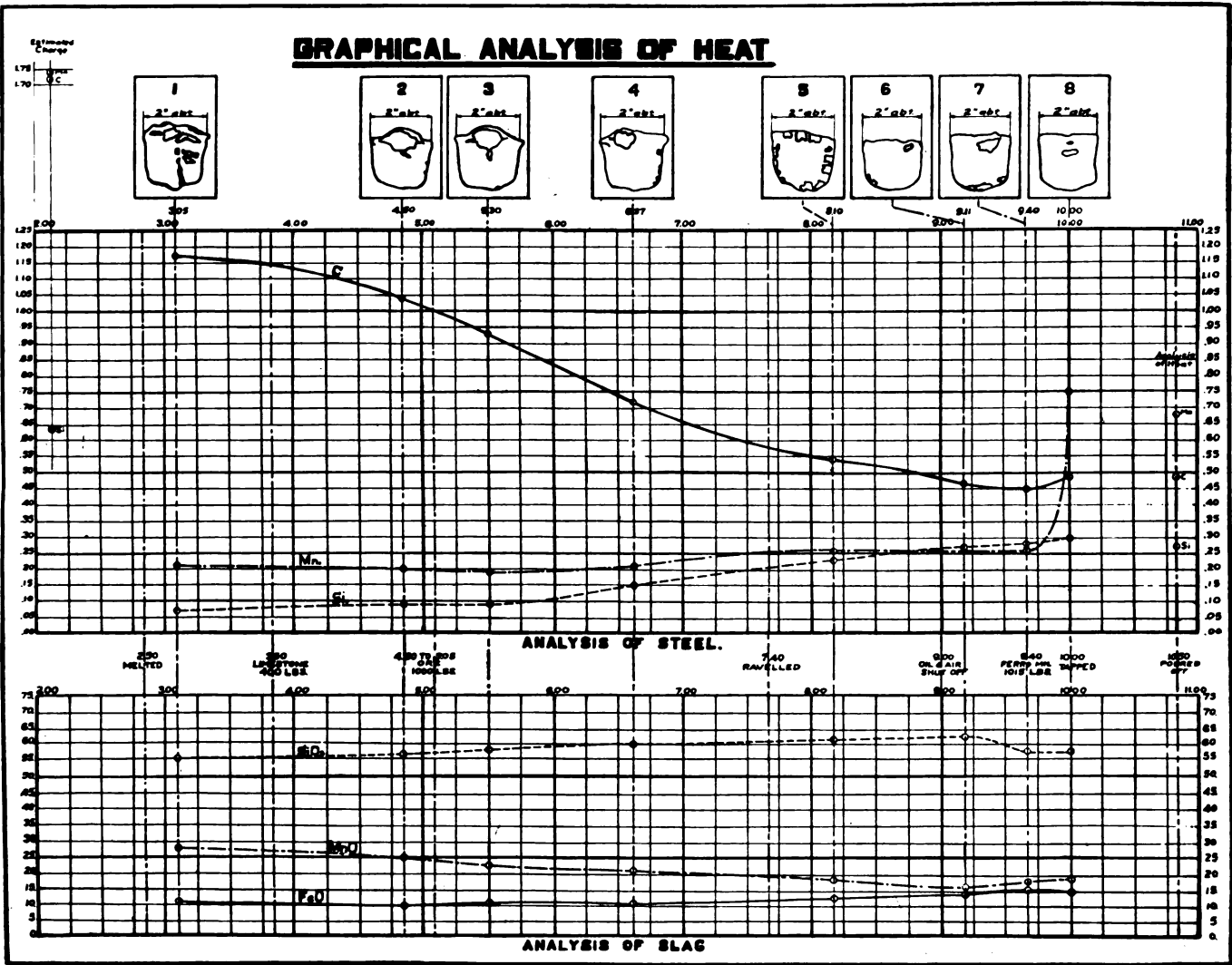


Fig. 1—Graphical analysis of heat.

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ingot and harder to break up by subsequent forging and heat-treatment, but even if this be eventually done, the non-metallic impurities will still remain and seriously affect the quality of the steel.

3. To bring out additional evidence as to the effect

of ingot impurities on the internal structure of the ingot, a longitudinal cross section may now be finished, machined and etched. As a result, there will appear certain dark lines symmetrically disposed on either side of the center line, and running in an oblique direction inward and

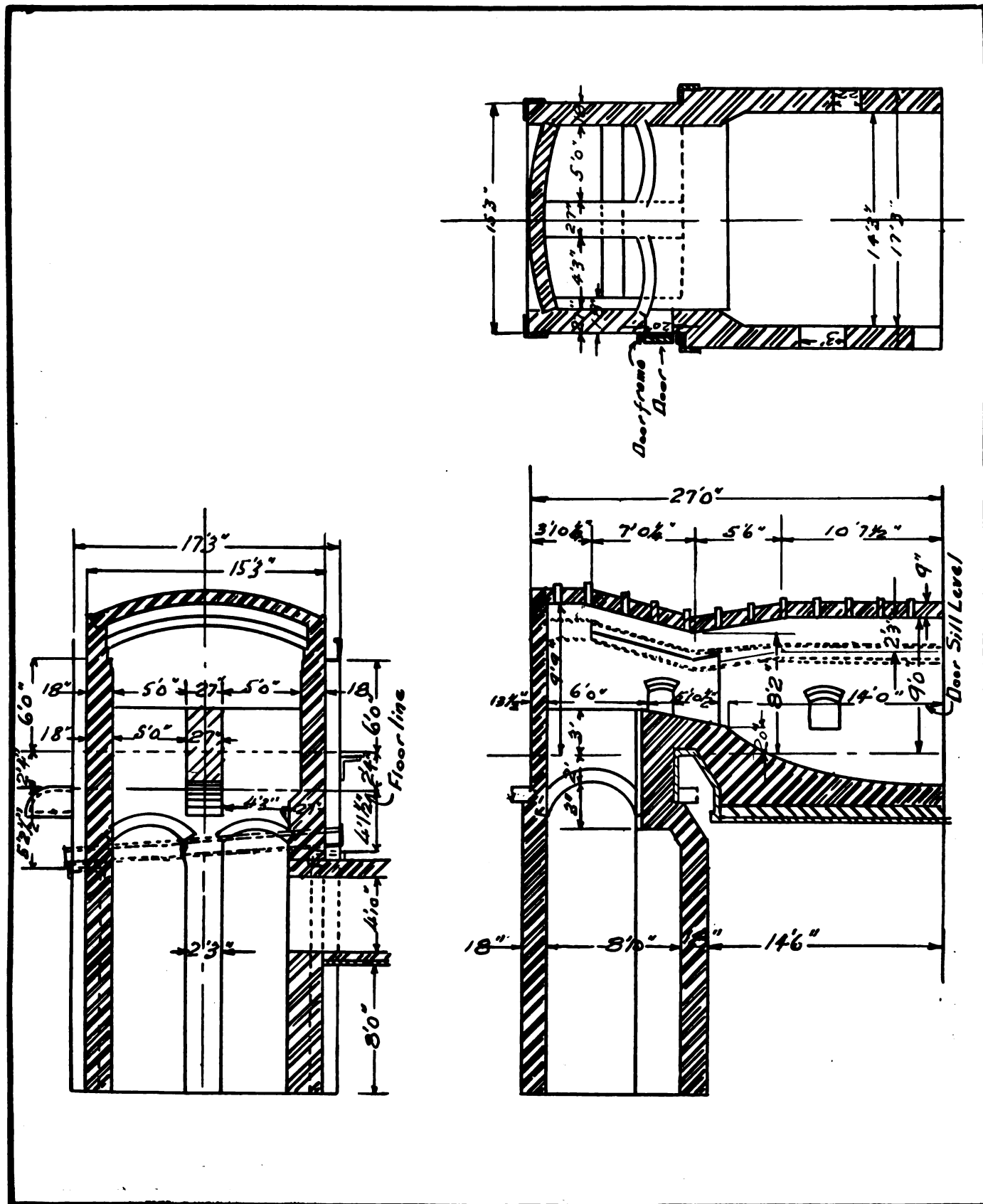


Fig. 2—Open hearth designed to burn oil.

upward. These lines are the paths taken by metallic segregations high in phosphorus and sulphur, mixed with silicates and sulphides of manganese, resulting from the reactions in the steel, after it had been poured into the mould. These impurities remain fluid during the time of crystallization, part of them becoming entangled among the ingrowing crystals, while the rest are driven inward by the solidifying shell, and upward on account of being lighter than the surrounding mother metal, and as they progress toward the center and top of the ingot, they coalesce into larger and larger globules and increase more and more in number. They may later be identified in the forging made from the ingot, the metallic segregations high in phosphorus and sulphur as "ghost lines,"

especially in the bore of hollow forgings, and the silicates of manganese as "slag pockets" or "sand splits" in the machined forging, and also as streaks of "slag" across transverse test bars.

The composition of the "ghost lines" was determined at Midvale some years ago by slicing a transverse section off the end of a large hollow forging, made from an ingot which had been cast in a sand lined mould and which therefore, had a great many well defined "ghost lines" in the bore. On etching this section, the "ghost lines" were plainly seen as bright spots, increasing in number from the outside to the bore. These spots were drilled with a 3/32 in. drill, and the drillings, as well as the surrounding metal, analyzed with the following result:

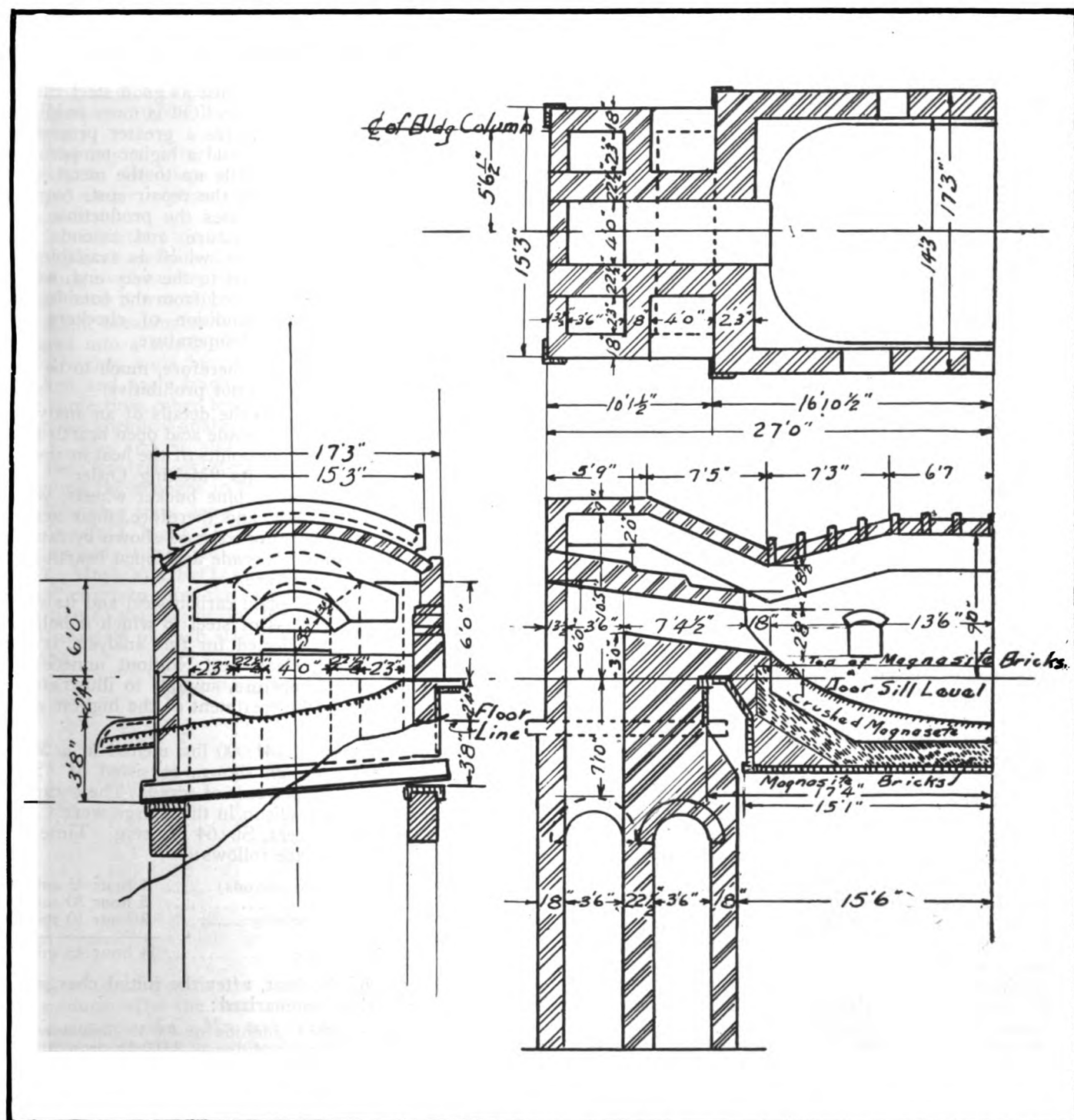


Fig. 3—Open hearth designed to burn producer gas.

	C	Mn	P	S	Si
	per cent	per cent	per cent	per cent	per cent
Ghost lines	.497	1.026	.082	.116	.268
Surrounding metal	.498	.894	.030	.047	.316

In regard to the silicate of manganese opportunity was offered for its analysis by finding a large quantity that had escaped to the bottom of the shrinkage cavity in a 63-inch octagon ingot of basic steel, which had had the usual finals for this kind of steel of ferro manganese, ferro silicon and aluminum. The lower part of this silicate was a yellow-blue, solid enamel, while the upper part was very light and porous, and violet-blue and black in color. The compositions were as follows:

	Si O ₂	Mn O	Al ₂ O ₃	Fe O, etc.
	per cent	per cent	per cent	per cent
Lower part	51.60	40.60	7.88	trace
Upper part	50.34	29.94	18.90	trace

The defects in the steel, resulting from these lines of ingot impurities, will be necessarily more serious in basic steel than in acid, specially in regard to the oxides.

The much less serious effect of the segregations high in phosphorus and sulphur, which are the cause of ghost-lines, may be modified in basic steel because of the fact that this, as a rule, is lower in phosphorus and sulphur than acid.

Having explained what in my opinion are the defects caused by oxides on the internal structure of the ingot and therefore the advantage of the acid open hearth over the basic in being able to produce a steel more free from these oxides, permit me to take up in order:

First—The proper design of the furnace for high grade acid open hearth steel.

Second—A comparison between producer gas and fuel oil for melting.

Third—An analytical description of the acid open hearth process as carried out by Midvale.

First—Two designs of open hearth furnaces are shown, one as adapted for producer gas and the other for fuel oil. The nominal capacity of both is 50 tons, although charges up to 140,000 lbs. may be melted. There is nothing peculiar in the designs, as far as valves, flues, regenerative chambers or stacks are concerned, and these parts are therefore not shown. The only unusual feature is the great height of the furnace roof over the door sill level. This has been a gradual development, and has been found advantageous on account of the high and long sustained temperature necessary to carry out the chemical reactions during the de-oxidizing period of the process. The high roof provides a large combustion chamber, which permits a full and free development of the flame, and at the same time avoids damage by the intense heat to the roof and walls of the hearth. Even so it is advisable with a new furnace to keep it working a few weeks on the less exacting grades of steel, such as tires and bar steel, in order to harden it, before turning it over on the higher grades, as not even the best quality of silica brick will stand at the beginning the high temperature required for these. Towards the end of its life, the furnace as a general rule has again to be put back on lower grades of steel, as on account of impaired condition of checkers and draught, it is no longer sharp enough for making high grade steel.

No water cooled devices of any kind are used in the walls, roof or ports of the furnace, as it has been found as a result of many trials that even when used to a very limited extent, their cooling effect interferes with the sharp working of the furnace. The only water-cooled parts used are the charging doors, as they are far enough removed from the interior, not to have a noticeable effect on the heat.

It may be of interest to give here a comparison between the life of acid and basic open hearth furnaces, when melting with producer gas as well as with fuel oil, as measured by the average number of months from the time of charging the first heat after a general repair, until the time of tapping the last heat before the next general repair. The average number of months is given, rather than the average number of heats, on account of the great variety of heats made, some requiring twice as long a time as others, and is based on our records for the last five years.

Average Life of Open Hearth Furnaces.

Basic furnaces on producer gas	9.1 months
Basic furnaces on fuel oil	10.7 months
Acid furnaces on producer gas	11.2 months
Acid furnaces on fuel oil	12.6 months

Second—Not much time needs to be taken for the comparison between the two kinds of fuel, producer gas and oil available for melting. Just as good steel can be made with one as with the other. Oil is more oxidizing than gas, and, therefore, requires a greater proportion of pig iron in the first charge and a higher temperature after the heat is melted to settle up to the metal. On the other hand, oil cuts down the repair cost, requires fewer men per furnace, increases the production, permits better control of temperature, and extends that part of the life of the furnace, which is available for making high grade steel, almost to the very end, as the direction of its flame is controlled from the outside, and it is less affected by the condition of checkers and draught for generating a high temperature.

Taking it all in all, oil is, therefore, much to be preferred as long as its price is not prohibitive.

Third—Before going into the details of an analytical description of a heat of high grade acid open hearth steel, permit me to state the salient points of the heat in review, M.K. 13-126, as shown by its "Melting Order." The heat was made for steam turbine bucket wheels, which require tangential strength, and therefore, their acceptance depends on physical properties as shown by tangential test bars. Hence, high grade acid open hearth steel is used for their manufacture.

It is a simple heat of plain carbon steel and its treatment is typical of the class of steel to which it belongs. Though not especially selected for this analysis, it may be considered a good, clean heat, without unnecessary complications, and is therefore, suitable to illustrate the principles followed in the treatment of the highest grade of steel.

The initial charge of 141,000 lbs. melted in a 50-ton acid furnace of the design shown, consisted of 35 per cent of pig iron and 65 per cent of scrap. The estimated carbon, manganese and silicon in the charge were C 1.72 per cent, Mn. 1.74 per cent, Si. .64 per cent. Time consumed for heat in furnace follows:

Time of charging (in two periods)	1 hour 45 minutes
Time of melting	5 hour 50 minutes
Time in furnace after melting	7 hour 10 minutes

Total time in furnace

14 hour 45 minutes

The history of the heat, after the initial charge was melted, may be thus summarized:

1 hr. 0 min. after melted—addition of 400 lb. limestone.
2 hr. 0 min. after melted—addition of 1,000 lb. iron ore.
4 hr. 50 min. after melted—bath thoroughly reworked.
6 hr. 10 min. after melted—oil and air shut off.
6 hr. 50 min. after melted—addition of 1,015 lb. ferro-manganese.
7 hr. 10 min. after melted—heat tapped.
8 hr. 0 min. after melted—heat poured off.

The analysis of the go-ahead test, taken 1 hour 10 minutes before tapping, and the C, Mn, and Si, obtained from 1015 lbs. of ferro manganese added 20 minutes before tapping, are shown in the following table:

	C	Mn	Si
Anal. of go-ahead test	.49	.27	.24 (judged by fracture)
Addition of ferro mn.	.05	.57	.01
Total	.54	.84	.25

The table below shows the chemical composition of the heat as aimed at, and as obtained:

Composition	C	Mn	P	S	Si
Aimed at	.50	.65	.050	.050	.25
Obtained	.49	.68	.036	.038	.27

On account of the high percentage of Mn in the initial charge the slag remained greenish yellow in color from the time the heat was melted until it was tapped, with only slight variations in shade.

The steel was poured into 23-inch octagon moulds, 9 ingots = 10,500 lbs. and 3 ingots = 11,400 lbs. in weight.

The ingots, after cooling, were sent to the machine shop to be sliced into blocks, and these blocks were then forged under a steam hammer into bucket wheels for steam turbines.

To facilitate the analytical description of this heat, a graphical analysis chart has been plotted and drawn, showing its chemistry from the time it was melted at 2:50 a. m. until it was tapped at 10 a. m.

Eight breaking tests were taken at various times and poured into a standard test mould, about 2 inches deep by 2 inches wide by 6 inches long. These tests were broken and each fracture photographed as shown. At the same time other tests were taken, both of steel and slag, for chemical analysis. The steel tests were analyzed for C, Mn, and Si, and by plotting these determinations on the "analysis of steel" chart, curves were obtained showing the changes in these elements.

The slag tests were analyzed for SiO_2 , MnO, FeO, Fe_2O_3 , CaO, MgO, Cr_2O_3 , and Al_2O_3 , but to avoid confusion only the three most important of these oxides, SiO_2 , MnO, and FeO, were plotted on the "Analysis of Slag" chart, to show the changes taking place in the composition of the slag during the progress of the heat. The full analysis of each slag test is given on the following table:

Slags From M. K. 13—126.

	SiO_2	MnO	FeO	Fe_2O_3^*	CaO	Cr_2O_3	Al_2O_3	MgO	MnO	FeO	Fe_2O_3	CaO	Total
1	55.0	28.0	11.1	1.4	2.6	.3	1.4	.6	43.1				100.4
2	57.0	25.0	10.3	.6	3.9	.3	1.4	.6	39.8				99.1
3	58.7	22.7	11.0	.7	3.9	.2	1.9	.8	37.9				99.9
4	60.7	21.3	10.5	.9	3.3	.2	1.5	.8	36.0				99.3
5	62.2	18.7	12.7	1.0	2.5	.2	1.5	.7	34.9				99.5
6	63.0	16.5	13.9	.9	2.5	.2	1.5	.5	33.8				99.0
7	58.5	18.0	15.5	2.1	2.4	.2	1.6	.6	38.0				98.9
8	58.4	18.8	15.0	.4	2.4	.2	1.5	.5	36.6				97.2

*Any metallic Fe present was determined as FeO. This would result in a high figure for FeO, and a low figure for Fe_2O_3 .

Commencing with test No. 1, taken at 3:05 a. m., or 15 minutes after the heat was melted, its analysis shows the oxidation of C, Mn, and Si, during the time of melting by comparing it with the estimated percentage of these three elements in the initial charge. C has dropped from 1.72 per cent to 1.17 per cent Mn from 1.74 per cent to .21 per cent, and Si from .64 per cent to .07 per cent. A considerable percentage of Mn in the first charge is

highly desirable, because by its oxidation during the melting it gives a clean slag, greenish yellow in color, almost from the start and if the pig iron don't contain enough Mn, this deficit is made up for high grade steel by the addition of ferro manganese to the initial charge. A high percentage of both Mn and Si is also desirable in the initial charge on account of their oxidation being an exothermic reaction, facilitating the melting and giving a bath hotter and less sluggish with iron oxide by the time the charge is melted. Both these elements oxidizing at a lower temperature than carbon, their oxidation, as far as it goes, is practically complete by the time the charge is melted, while the carbon is still comparatively high.

Care is now necessary in the addition of iron ore for decarburizing the metal, as this is an endothermic reaction, absorbing heat and requiring a high degree of temperature for a vigorous reaction between the oxygen of the ore and the carbon of the steel. If the addition of ore is made too soon, or in too large a quantity, its chilling effect may so retard this reaction, that when finally the high temperature required is reached, and the bath goes into a boil, this will carry the decarburization so far that by the time the bath is well settled up, the carbon in the steel is well below the carbon aimed at. This would necessitate additions of spiegel and pig iron in order to recarburize the heat. Such a condition is almost fatal to the production of high grade steel, because the lower the carbon in the go-ahead test as compared with the carbon aimed at, and therefore the greater the addition of recarburizing finals, the greater will be the amount of silicate of manganese produced. This may quite likely lead later on to the condemnation of the forgings made from such a heat on account of "sand-splits" or "slag-enclosures," or on account of transverse test bars failing in extension and contraction, due to streaks of "greenish slag" or "woody structure," caused by these streaks, or in the case of projectiles, on account of cracks starting from small slag enclosures during the hardening process, or on account of the projectiles, selected for the firing test, breaking up in striking the face-hardened armor on account of the weakening effect of these concealed impurities.

Hence the reason for the note on the melting order: "Add no ore until two hours after melted." Except steadily increasing the temperature of the heat during these two hours, the only thing done was the addition of 400 lbs. of limestone one hour after the charge was melted. By displacing a certain amount of iron oxide in the slag, and making it more fluid, the limestone seems to put it in a better condition for subsequent reactions, at least where there is a low manganese content in the initial charge.

This, however, is in my opinion the only time, when addition of lime is of any value. If done later during the de-oxidizing period of the heat it will simply undo all the good that has been done because in replacing the FeO in the slag then, it will drive this into the steel to oxidize the silicon and manganese and make the bath again raw and unsettled.

At the end of these first two hours test No. 2 was taken. This shows the oxidation of the carbon, slow at first, on account of lack in temperature, now well under way. There having been as yet no addition of iron ore, this oxidation is caused by the rust in the initial charge, by oxidation of the charge in melting, and by the oxidizing effect of the flame itself.

The higher temperature of the slag is also shown by its slightly higher percentage of SiO_2 .

Test No. 3, taken 40 minutes after No. 2, shows the oxidation still going at the same rate, due to the

addition of 1,000 pounds of iron ore during the interval. The only effect of this addition on the slag is a slight increase in FeO, the SiO₂ continuing to rise and the MnO slowly decreasing by dilution with the SiO₂, taken up by the slag from the bottom along the slag line.

Test No. 4, taken one hour and seven minutes after No. 3, shows the oxidizing period at an end. The SiO₂ in the slag has now gone up from 55.0 per cent, 15 minutes after the heat was melted, to 60.7 per cent, while the two chief bases, MnO and FeO, have dropped from a total of 39.1 per cent to 31.8 per cent, in spite of the lower carbon in the steel. But most marked, and showing that the de-oxidizing period has set in, is the increased percentage of Si in the steel, caused by the reaction between the carbon of the steel and the SiO₂ of the slag, according to the formula: $2C + SiO_2 = Si + 2CO$. Whereas, during the melting of the charge on account of the low temperature then prevailing, the oxidation of Si was going on at a much greater rate than the oxidation of the carbon, with the steadily increasing temperature this oxidation of Si was first checked, then held, until finally a complete reversal has taken place, the very high temperature now reached having so increased the affinity of carbon for oxygen, that it is able to reduce Si out of SiO₂, leaving the Si free in its nascent, and therefore most efficient state, to de-oxidize the steel, as shown by the increasing solidity and freedom from blow holes of subsequent tests. This reaction is the essential point, that accounts for the difference between acid and basic steel, and that makes acid steel superior to basic.

What has just been said in regard to the effect of the increased temperature on the relative affinity of C and Si for oxygen, is also shown to have taken place in the relative affinity of C and Mn for oxygen, the C now reducing Mn out of the MnO of the slag, the nascent Mn also assisting in the de-oxidation of the steel. This manganese reaction, however, which also may take place in a basic open hearth heat, is much less effective than Si in de-oxidizing the steel, because the de-oxidizing effect of Mn is much less than that of Si, the latter, according to Brinell, being 5.2 times more effective than the former.

Test No. 5 shows the characteristic "worm holes" well developed from the increased absorption of Si, which has gone up to 23 per cent. The only thing done with the heat between tests Nos. 4 and 5 was to give the bath a thorough revelling with steel bars to facilitate the liberation of gas. Nothing else is now being done except to keep on pushing the temperature higher and higher and thus promote the reaction between C and SiO₂.

The reason why the carbon curve is still on a downward slope, in spite of the now well settled up condition of the bath, is no longer the reaction between the iron oxide of the slag and the carbon of the steel, which occurred during the oxidizing period of the heat, but the reactions of the de-oxidizing period between the carbon in the steel and the SiO₂ and the MnO of the slag, the Si and Mn, as previously explained, being constantly reduced to act as carriers in de-oxidizing the steel, while the CO, resulting from this reaction, bubbles slowly up through the slag. Assuming that when No. 5 test was taken, the percentage of Si and Mn in the steel were the same as when No. 3 test was taken, it may be shown by a simple calculation, that the carbon then would have

been about .67 per cent, instead of having dropped to .54 per cent, so that but for this later reaction of the de-oxidizing period, the carbon line would have been almost horizontal.

Test No. 6 shows the de-oxidizing process almost complete, the "worm holes" of the previous test having been nearly obliterated by the steadily increasing percentage of Si. The heat would now have been ready for the final addition of ferro manganese made just before tapping, except for the fact that the carbon, according to the first go-ahead test, was still a little too high, or .53 per cent. A second go-ahead test had therefore been taken out 10 minutes ahead of test No. 6, and on this being reported as being down to .49 per cent carbon the ferro manganese was added at 9.40 a. m., and the heat tapped at 10.00 a. m., or 20 minutes later.

Test No. 7, taken just before adding the ferro-manganese, is very little different in appearance from test No. 6, while test No. 8, taken after the addition of ferro-manganese, and just before tapping the heat, is absolutely solid. The Si in this test was .30 per cent, while the Si in the heat test, taken while pouring the steel into the moulds, was .27 per cent, which shows that the Si in the steel, while still in the furnace, is higher in the stratum close to the slag, from which test No. 8 was taken, and where the reduction of Si from the slag is taking place, than the average Si of the whole mass of steel.

Aluminum and titanium are never used for de-oxidizing steel in which transverse strength, as determined by transverse tests, is required, because the oxide of these elements have a very baneful effect on the physical properties of such tests, even when used very sparingly. It is difficult to believe, but it is nevertheless a fact, that this effect of aluminium, added into the ladle at the rate of one pound of aluminum to 10,000 pounds of steel, and held 25 minutes before pouring, very likely will cause the condemnation on account of failing test bars if a gun forging made from this steel.

There is one more point in regard to the chemistry of this heat that requires an explanation. That is the shutting off of the oil and air, which also implies the lowering of the stack-damper, one hour before tapping.

It may be noticed on the "Analysis of Steel" chart, that this had no effect on the C, Mn and Si curves.

On the "Analysis of Slag" chart, however, the result was a sudden drop in the SiO₂ curve, and a corresponding, but less marked, rise in the MnO and FeO curves. This, of course, does not mean a loss of SiO₂, as far as the actual weight of this oxide in the slag is concerned. What has occurred is an absorption by the slag of an additional amount of the two basic oxides, MnO and FeO, from the same source, thus making the slag less acid than it was before.

The thermal effect was a very decided cooling of the slag, while, on account of slag being a poor heat-conductor, the temperature of the steel underneath the slag was, by comparison, only slightly lowered.

The reasoning which first led me to try this treatment with the point in view of still further de-oxidizing the steel, was this:

As the temperature of an acid heat rises, by degrees de-oxidizing the bath through the reactions between the slag and the steel made possible by this rise in temperature, a point is finally reached where this reaction has to be stopped, in order not to get the steel too high in Si. (Continued on page 385)

Development of Hot Process Water Softener

Process Takes Advantage of the Fact That Chemical Reactions
Are More Rapid and Complete in Hot Water Than in Cold Water.
Effect of Heat Upon Reactions.

By GEORGE GIBSON.

THE hot process softener in its present form is a recent development. By taking advantage of the fact that chemical reactions are more rapid and complete in hot water than in cold water, more efficient removal of scale and sludge forming substances are obtained. The apparatus performs the functions of the open-water heater usually found in steam boiler plants, in addition to those of a softener, and less space, lighter foundations, less housing, less piping and fewer fittings are required than for a cold process softener plus an independent heater. There are several reasons why scale-forming matter is more completely removed from hot water than from cold water.

Effect of Heat Upon Reactions.

Chemical reactions are enormously accelerated by heat. This is a well known and generally recognized fact, and was used in the household for ages before it assumed the dignity of a law of chemistry. Everyone knows that dishes and clothes are washed more rapidly and thoroughly in hot water than in cold water. Paper pulp is causticized in hot water, etc., etc.

Some years ago experiments were made in the chemical laboratory of the Harrison Safety Boiler Works to determine the effect of temperature upon the reactions which take place between softening reagents and scale-forming matter in boiler feed water. The results are shown graphically in Fig. 1.

It will be seen that the reduction in hardness, that is, in content of calcium and magnesium salts, is much greater at the end of 10 minutes in water at 210 degrees F. than at the end of five hours in water at 50 degrees F., in fact 24 hours treatment in cold water does not bring the scale-forming matter down as much as does 10 minutes treatment in hot water. Subsequent heating to the boiling point of the sample which has stood at 50 degrees F. for five hours reduces the magnesium hydrate to less than 1 grain per gallon, but the same result is obtained in hot water in 10 minutes. In performing these experiments, only sufficient softening chemical was added to combine with the scale-forming substances. In practice a slight excess is used, which reduces the hardness to lower figures.

Effect of Heat Upon Sedimentation.

The precipitates resulting from the transformation of scale-forming substances also settle more rapidly and completely from hot water than from cold water. Solid particles suspended in water settle to the bottom if their density is greater than that of the water or rise to the top if their density is less than that of the water. The force acting upon the particles is its weight less the weight of water displaced, and the force by which it is resisted depends upon the extent of its surface and the viscosity of the fluid in which the particle is suspended, multiplied by the velocity of fall. A maximum velocity is reached at which the retarding force is just equal to the accelerating force.

Obviously a large particle will settle more rapidly than a small particle because it contains a greater mass,

and hence is acted upon by a greater force, in proportion to its surface.

In a water softener the precipitated particles are of various sizes, and possibly of different densities, but any given particle will fall through the water at a rate depending upon the viscosity and it is therefore of interest to note that the viscosity of water at 212 degrees F. is only one-sixth of the viscosity at 32 degrees F., while as between water at 68 degrees F. and water at 212 degrees F., the increase in velocity of fall will be about four times.

Therefore, the rate of flow can be four times as great

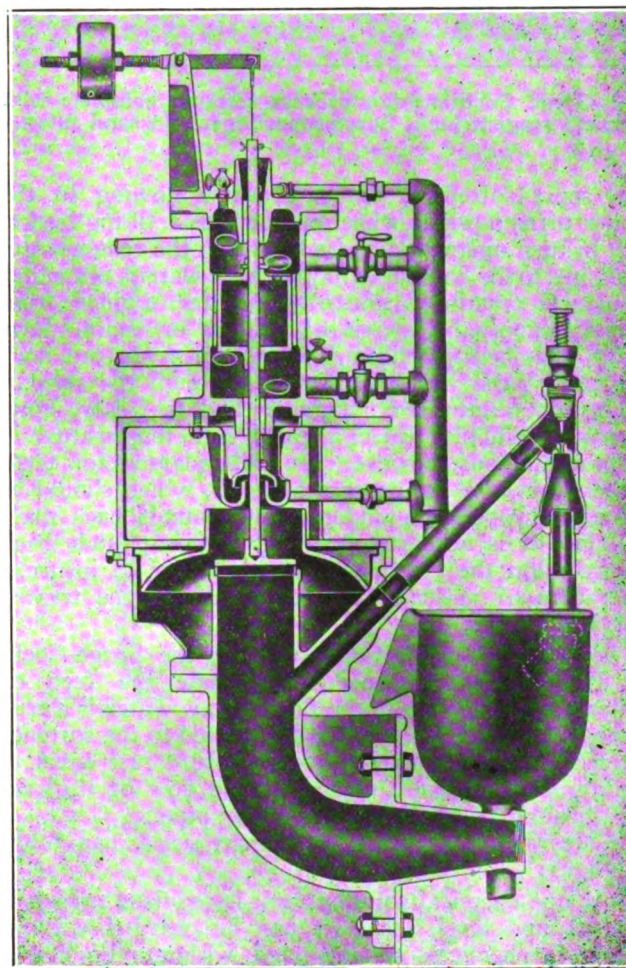


Fig. 1—Chemical proportioner.

in a hot-process softener as in a cold process softener without carrying particles of a given size to the pump supply pipe, or, to put it in still another way, with a given rate of flow through the settling chamber much smaller particles can be separated out in the hot-process softener than in the cold process softener.

It is therefore plain why the preliminary heating of the water, a feature which is peculiar to the hot-process softener, gives more complete chemical reactions and

more thorough removal of the resulting precipitates.

For proportioning the re-agents to the raw water supply in softeners various mechanical arrangements have been devised.

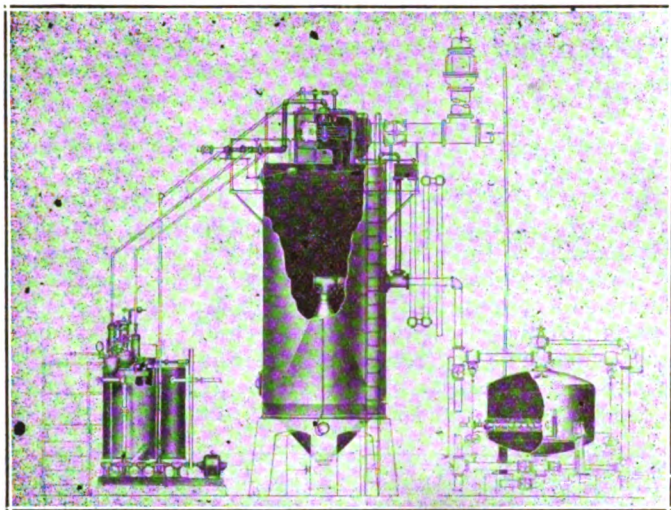


Fig. 2—Sorge Cochrane hot process softener complete with chemical reagent tank, flow proportioner and sand filter.

In some softeners, the raw water flowing to the softener turns a water wheel or operates a tilting bucket which in turn operates dippers by which the reagents are ladled out to be mixed with the raw water. In other softeners, a certain portion of the water, divided from the main supply by means of orifices or weirs, flows through chambers containing the reagents. In one such proportioner, the water in flowing through the reagent tank becomes saturated. This method is faulty, however, since solubility varies greatly with temperature.

These methods, however, are well adapted for feeding chemicals to a hot-process softener, which should be designed for operation under a few pounds back pressure, since it is necessary to carry a few pounds back pressure upon the exhaust steam, in order to insure a temperature of at least 205 degrees F. of the treated water at all times.

The chemical proportioner used in the Sorge-Cochrane Hot-Process Softener to regulate the feed of chemicals in proportion to the flow of raw water is a true flow proportioner. The chemical to be fed to the softener is forced through an orifice by a pressure just equal to the differential pressure set up by the flow of the raw water through an orifice in the supply pipe.

Besides being accurate the device used has other advantages:

Only one chemical solution tank is required, which is at the ground level, where it can be charged without hoisting of chemicals or inspected without climbing a ladder.

The motor which drives the circulating pump also drives agitating paddles in the tank. Milk of lime can thus be kept in suspension and fed as well as purely fluid reagents. The large saturator tanks necessary where lime water is used are eliminated and the difficulty due to the fact that lime water varies in strength according to temperature is avoided. Solutions of caustic soda or sodium carbonate, lime water, milk of lime, or any mixtures, are all handled equally well and fed accurately. The accuracy with which the solution is fed is well within 2 per cent, which is closer than attendants will measure

out chemicals into the chemical tank.

The Sorge-Cochrane Hot Process apparatus, as may be seen in Fig. 2 is simple and compact. The open heater, with an oil separator attached for purifying the exhaust steam used for heating the water, is mounted directly over the reaction and sedimentation chamber. The water is heated to steam temperature by spraying it over trays, which also serves to release oxygen and other dissolved gases. It is then mixed with the reagents and falls directly into the sedimentation tank. There is no constricted piping between heater and tank to become choked with scale. In fact, the water does not pass through piping from the time when it is first heated until it has been through the sedimentation chamber, even the overflow receiving only settled water.

The precipitated matter deposits in the conical bottom of the sedimentation chamber, from which it can be quickly washed by the opening of a single valve. In order to eliminate convection currents, the hot water and the softening reagents are delivered at the top, and travel slowly to the bottom, from which the clarified water is drawn off by an inverted funnel. The precipitates formed when the water is first mixed with the chemical fall through the water below, securing a screening effect and gathering together the small particles. All precipitates are carried to the conical bottom of the tank from which they are readily blown out by opening a sludge valve at the lower end or apex of the cone.

Filters.

The removal of scale forming matter at high temperature by sedimentation is so effective that for many waters and plant conditions it is entirely practicable to dispense with filters. Many softeners are accordingly installed without filters and are successfully protecting the boilers from scale and corrosion, even though the softened water contains a slight amount of suspended matter. Other conditions demand the use of filters, for which a low-pressure sand filter is placed between the sedimentation tank and the boiler feed pumps or meter, the water flowing through the filter by gravity. These filters deliver a crystal-clear water which contains no solids except those in solution and no mud-forming properties except the amount which is below the exceedingly low limit of solubility of calcium and magnesium

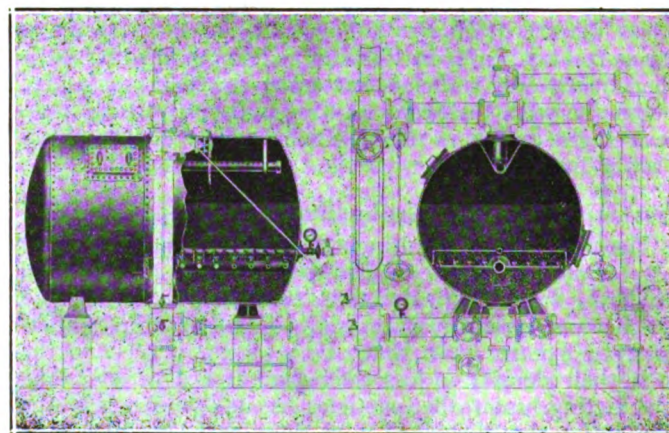


Fig. 3—Horizontal sand filter.

momocarbonates, silica, etc., at the boiling point. This water will leave no troublesome deposit in the feed lines, pumps or meters and is particularly suitable for boilers operated at high ratings.

Heating Furnaces and Annealing Furnaces

Coal on the Grate—Natural Draft—Semi-Gas Firing—Notes on Stoker Firing—Ratio of Grate Surface to Hearth Area—Quantity of Coal Burnt Per Square Foot Grate Surface and Hour.

By W. TRINKS.

PART XVIII.

HAND FIRED coal grates on heating furnaces and annealing furnaces with natural draft are today quite scarce, and rightfully so, because they result in enormous waste. The arrangement of the grate is diagrammatically shown in Fig. 117. Coal burns just as it would on a boiler grate; when the gases leave the fuel bed they are not completely burned because the hot carbon dioxide which is formed in the lower layers of coal, is reduced to carbon monoxide in the upper layers. Combustion can be made complete by the presence of oxygen above the fuel bed. If the coal is in the shape of large lumps and does not break up into small pieces in the fire, the air which is necessary for completing combustion above the fuel bed will pass through the air channels formed between the large lumps. Mixing of air and combustible gases will then be fairly good,

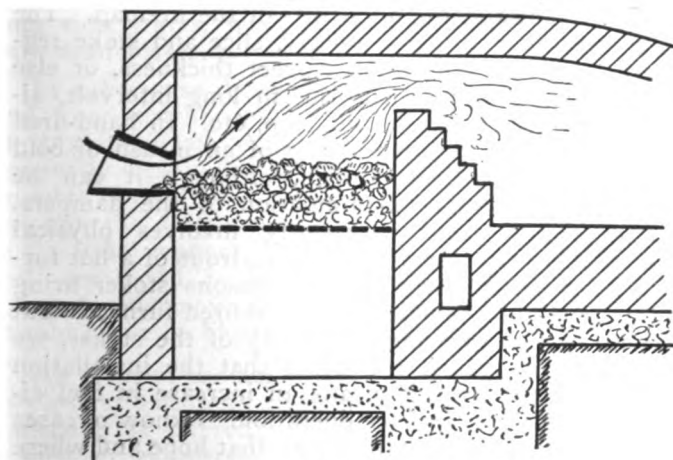


Fig. 117.

and combustion will be almost complete before the gases strike the steel. For that reason large lump coal is desirable for this method of firing. If, on the other hand, run of mine or small lump coal is used the air for combustion above the fire cannot pass up through the coal and must come in through openings above the fuel bed, for instance, through the fire door, see the arrow in Fig. 117. In that case the mixing of air and of combustible gases is very poor and combustion frequently extends away into the flues or even into the stack.

Since, in this type of furnace grate, the force for moving air and gases is furnished solely by stack draft, there must be draft (that is to say, a partial vacuum) in the furnace. Air is drawn in through every crevice and through the openings around the furnace doors. Oxidation of the steel is excessively great, the degree of oxidation depending upon the tightness of the furnace structure and upon the care

of the heaters. In furnaces with natural draft, the door frames and sills are occasionally made to extend outwardly for six inches or more so that the heaters can pile up coal or coke, ashes or cinders on the outside of the door and thus reduce any infiltration or oxidation. This procedure is, of course, more or less of a nuisance. In order to keep the inrush of cold air into the furnace from being excessive, engineers use a large grate in comparison to the hearth area. However, it is unnecessary to give dimensional data on this type of firing, because it is never used in new installations.

It is quite evident that to maintain a slight pressure in the heating chamber of the furnace, we must blow air through the grate, which means closing up

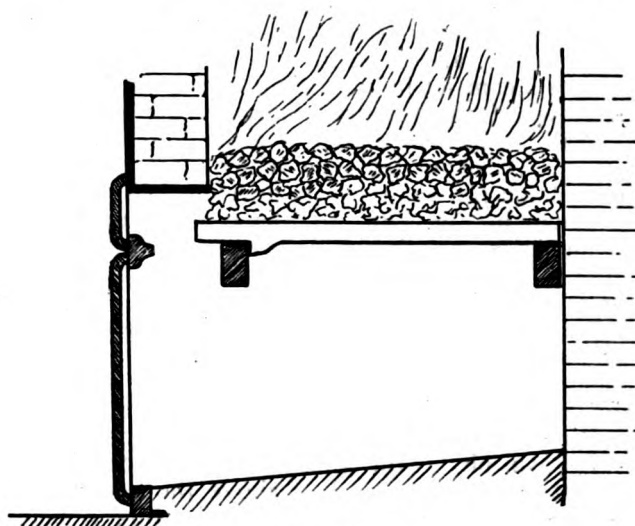


Fig. 118.

the ash pit. While this action prevents infiltration of air and thereby protects the steel from oxidation, it also interferes with combustion unless air is blown in above the fuel bed. It is true that the latter procedure is not absolutely necessary, because free air can pass up through the fuel bed, if good lump coal is used, but the expense and trouble of securing such coal make its use undesirable. For that reason, air is blown in above the fire by a blower. This portion of the air is commonly referred to as secondary air. If such air is not used the flame is very smoky with a thick fuel bed and very rash with a thin fuel bed.

The closed ash pit naturally interferes with cleaning of the fires. For that reason, the ash pit door is occasionally split up into two sets of doors as shown in Fig. 118. The upper door is made quite shallow, but is large enough for operating the slice bar.

One great trouble with coal fired furnaces is the clinker which forms and sticks to the brick. Fre-

quently (depending upon the rate of combustion and the composition of the ash), the clinkers build up from the four sidewalls of the grate to such an extent that they must be chiseled off every Sunday. Clinker trouble is reduced if steam is passed up through the fuel bed. It is a well known fact that steam breaks up clinker and keeps it from building up on the walls. Besides, if a mixture of air and steam is passed

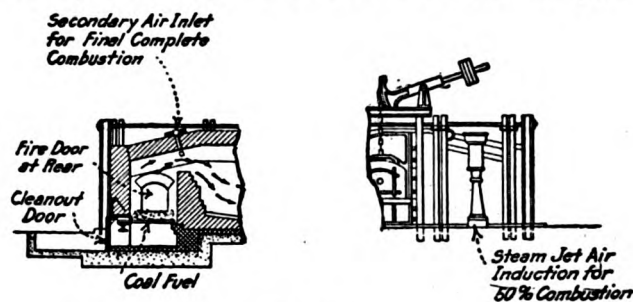


Fig. 119.

through a thick fuel bed, the latter is practically converted into a gas producer, and furnaces fired by this method are known as semi-gas fired furnaces. In Part 15, mention was made that the application of semi-gas firing allows a uniform distribution of heat over the hearth by introduction of secondary air in various places.

In practice, the considerations of the foregoing paragraphs are carried out in various ways. In many furnaces a steam jet induces air into the ash pit, while a fan blower furnished dry secondary air beyond the bridgewall. Fig. 119 shows a grate and furnace of this type. A steam jet type which does away with the closed ash pit was recently developed in Germany. It is shown in Fig. 120. In this type of furnace the grate lies in a trough through which air and steam are blown. The refuse moves over to a back grate where opportunity is given for burning out the carbon from the ashes. The raking out of the ashes is made easier than in the closed ash pit type.

Another method consists in having the same blower furnish both primary and secondary air and in running exhaust steam from an engine or hammer into the ash pit. Still another method consists in raising steam in a water box above the level of the grate (see Figs. 121 and 122), and leading it below the grate. This arrangement keeps the clinkers from building on to the brick and can be used where neither

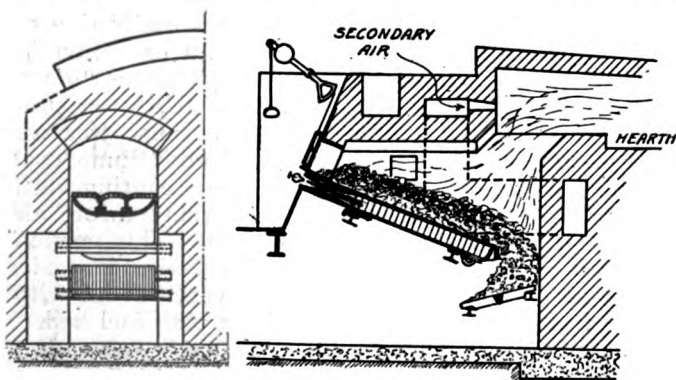


Fig. 120.

exhaust steam nor live steam are available. On the other hand, it requires a naturally soft water. If the water is hard, the box promptly fills up with scale.

This criticism applies particularly to the plain box, Fig. 121. The water box of Fig. 122 is much better, for several reasons. The part which fills up with

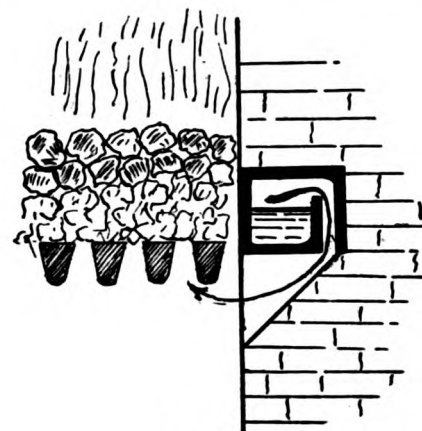


Fig. 121.

scale can be removed without disturbing the brickwork above the box. The part which is exposed to the fire can expand and contract independently. The top of the box, not directly in contact with the water, is protected against heat by a layer of brick. This box (Fig. 122) was designed by the George J. Hagan Company, furnace engineers, Pittsburgh. Patent protection has been applied for.

The operation of any hand-fired grate depends upon the skill and the good will of the fireman. The latter may shovel coal regularly, slice and stoke regularly, keep the fire at the correct thickness, or else he may shovel large quantities in long intervals, allow ashes and clinker to build up, etc. In hand-fired furnaces there is the possibility of an inrush of cold air when the fire door is open, although it can be avoided by a proper manipulation of the dampers. Finally, hand firing necessarily involves physical labor which is not very pleasant in front of a hot furnace. For all of these various reasons stoker firing has become quite popular with coal-fired furnaces, but in spite of this growing popularity of the stoker, we should guard against the belief that the installation of a stoker necessarily means an increase in fuel efficiency and better furnace operation. I know of cases where stokers were installed with that hope and where they were later taken out, because the results were inferior to hand firing, the furnaces being so cramped that there was not room enough for flame development in a stoker. What the mechanical stoker does accomplish is to abolish the physical labor of shoveling, and that in itself, is enough to attract a somewhat higher class of labor, but unfortunately, not all

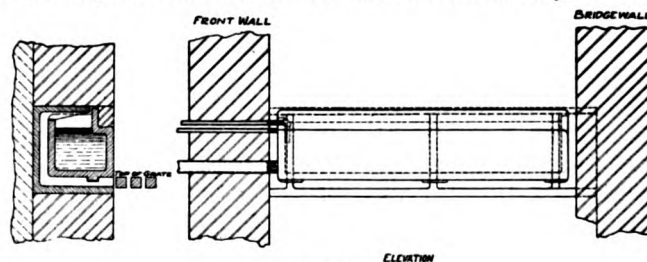


Fig. 122.

stokers do away with the physical labor of clinker pulling, which feature should be carefully considered in the selection of a stoker for furnace work.

From reasoning in the early part of this installment it is clear that only those stokers can be considered which work with pressure in the ash pit. It

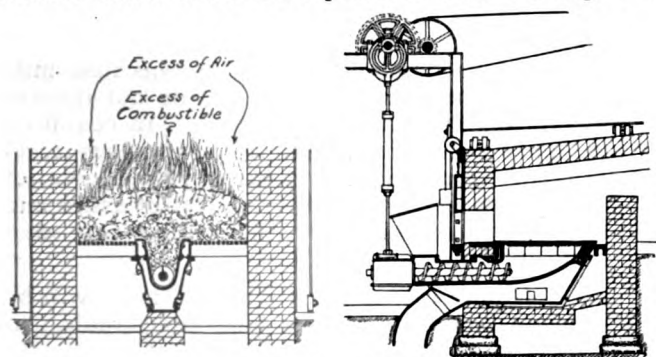


Fig. 123.

also follows that stokers should act as semi-gas producers, which condition requires a deep fuel bed. Prevention of excessive smoke under this condition is obtained with underfired stokers, two types of which are in common use on furnaces, namely the type "H" of the Combustion Engineering Corporation, see Fig. 123, and the Jones stoker of the Underfeed Stoker Company of America, see Fig. 124. In either type, the green coal is pushed in through a retort. In the type "H" stoker feeding is accomplished by means of a screw, while a ram is used in the Jones stoker. One stoker empties the mixture of coke, ash and clinkers onto side grates, while the other stoker empties it onto dead plates.

In either case there usually exists a zone of heavy fuel from which combustible gases rise, and a zone of thin fuel from which excess air rises, unless an unusually heavy fire is carried, in which case combustible gases rise without excess air coming in through the stoker. Secondary air is then supplied in the usual manner, for instance, through the bridgeway, see Fig. 125. For good combustion and for the sake of efficiency, secondary air must be dry. It should never be blown in by a steam jet.

As proof of the statement that a stoker needs just as close attention as a hand fired grate, the following reasoning is offered: If, in a stoker, the blast is turned on too strong in comparison to the fuel feed, the fuel bed will become thinner and thinner, the fire will become too hot, and a rash, oxidizing flame will result. If, on the other hand, the blast is turned down too low, the fire will gradually become thicker, and colder. Any fuel bed is inherently unstable, but in hand firing, the fireman discerns thin, bright spots and covers them up. The constant necessity for

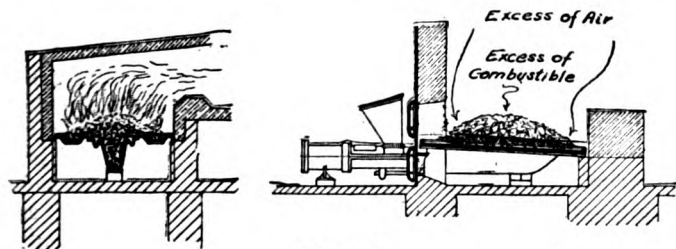


Fig. 124.

watching the fire arising from hand firing does not exist in stoker firing; in consequence, the danger of letting the fire get out of adjustment is much greater.

The grate area in coal-fired furnaces varies between the limits of 18 per cent and 30 per cent of the hearth area. The smaller area holds for good lump-gas coal. It might, at first thought, be imagined that high temperature furnaces (2,100 to 2,300 degrees F.) would require large grate surface for a given hearth and that low temperature furnaces could get along with a smaller grate. But this is not so. A low temperature (say 1,500 to 1,600 degrees F.) furnace needs a low temperature grate and the latter is obtained

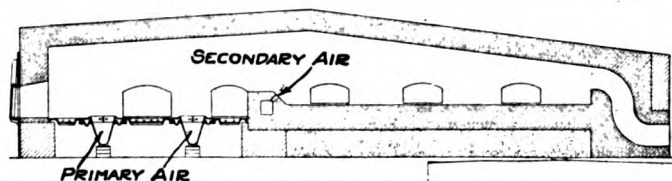


Fig. 125.

only by a low rate of combustion. The temperature of the top of the fuel bed is determined as a balance between heat addition (due to combustion) and heat abstraction (due to the heat in the gases leaving the fuel bed and due to radiation). From this fact, it follows that a high rate of combustion produces a hot fire, and a low rate of combustion results in a dull fire. But since the latter is wanted in a heat treating or in an annealing furnace, a slow rate of combustion must be used, which, of course, means a large grate.

Expressed in different terms, the required grate surface may be given by the quantity of fuel burned or gasified on it. Generally speaking, that amount depends upon the quality of coal, size of lumps, volatile matter, quantity and composition of ash, upon the design of the grate, and upon the draft, but for heating furnaces, additional considerations enter. Some of them were mentioned before and need not be repeated; there is, however, one additional consideration, namely protection of the brickwork and of the stoker. While it is possible to burn 75 pounds of good gas coal per hour on one square foot of grate surface with one inch of water draft, the temperature of the fuel bed resulting from so high a combustion rate burns out the roof over the grate and over the bridgeway in a few days. For that reason, 25 pounds per square foot and hour are seldom exceeded on heating furnaces for high temperature work, while in annealing furnaces 10 to 12 pounds per hour and square foot are an average value. It is, of course, quite possible to burn coal at a higher rate in annealing furnaces, but in that case, the grate surface becomes much too small in comparison to the hearth area, and it becomes difficult, if not impossible, to

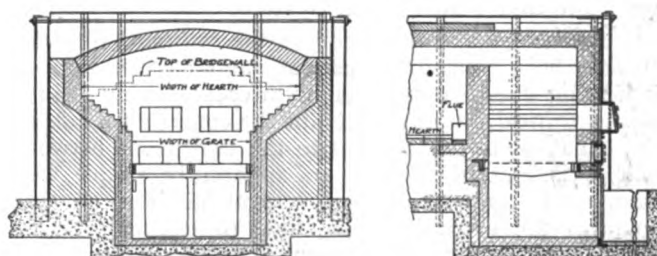


Fig. 126.

secure uniformity of temperature all over the hearth. The truth of this statement will be realized from the steps which we find necessary for securing fairly uni-

form temperature with rate of combustion as low as 8 pounds per square foot and hour, see Fig. 126. In this illustration, the width of the grate is less than that of the hearth. Uniformity of temperature is obtained by a gradual widening of the firebox in an upward direction, and by the shape of the top of the bridgewall.

In computing the rate of combustion on stokers, it is customary to divide the coal burned or gasified per hour by the horizontal area of the firebox, which equals the area of the retort plus that of the side-plates. If that method of calculation is followed, the rate changes between 6 pounds and 32 pounds per square foot and hour. The latter rate is a catalogue rate which should not be carried out in practice because it results in a high maintenance cost due to burning out of tuyeres and due to excessive formation of clinkers.

In view of the facts that coal must be delivered to every coal-fired furnace, that ashes must be hauled from it, and that the removal of clinkers causes difficulties, the question is justified why coal-fired furnaces still exist. The answer is that, in many localities, coal is very much cheaper than oil, city gas or natural gas, if the latter is at all obtainable, and that the installation of a gas producer or a water gas gen-

erator does not pay for a single furnace or for a small group of furnaces. Furthermore, it has been found that the fuel economy which is actually obtained with gas-fired or oil-fired furnaces is, in many cases, much lower than might be expected from the theoretical possibilities of such methods of firing, because misadjustment and an over-supply of fuel do not involve any exertion on the part of the heater. In coal-fired furnaces, and particularly in hand-fired furnaces, careless operation results in increased physical labor of shoveling, coal passing, and the removal of ashes and clinkers. The heater has a selfish interest in economical operation.

For all of these reasons, coal fired furnaces will be used and installed right along. One undesirable feature in their installation is the tendency to add more and more coal-fired furnaces to a growing plant, even after the latter has grown to a size which would well justify the installation of gas-making equipment.

Reference is made here to part XV, where a semi-gas fired furnace was described with the fuel bed under the floor.

The coal consumption per ton of steel heated is not discussed in this installment, because it depends upon the utilization of flue gases for preheating steel or combustion air.

Recent By-Product Coke Oven Developments

Chiefly a Description of the Engineering Developments of the Koppers Ovens—The Triangular Flue System, Its Advantages and the Resultant Increased Efficiency.

By JOSEPH BECKER and F. W. SPERR, JR.

DURING the past five years of intense activity in by-product coke oven construction, there has been steady progress in engineering improvement. It is the purpose of this paper, not so much to enumerate the various improvements in detail, as to discuss certain developments of major importance, that have been made by The Koppers Company. These are all developments of the Koppers oven, and retain the basic principle of cross regenerative heating that has been the prime factor in the remarkable success of this oven. Fifteen years of intensive technical effort have been unable to modify or replace this principle with any degree of success; but the improvements which will be described, carry its application to a higher degree of efficiency and economy than was a few years ago considered possible.

The Triangular Flued Oven System.

The structure and operation of the ordinary Koppers oven have been frequently described and are well known. The heating flues are rectangular in cross section. Each separate vertical flue transmits, in the course of a coking cycle, equal quantities of heat to the two ovens between which it is located. Now, an apparently simple, but fundamentally important, improvement has been effected by making the vertical heating flues of triangular cross section. Fig. 1 shows this system in actual construction. It may be convenient to compare Fig. 2 which illustrates the vertical flues of the ordinary Koppers oven. Reference also may be made to Fig. 3 which shows a perspec-

tive view of a battery of triangular flued ovens of the combination type, which will be more particularly discussed later. The sectional cuts in this view are arranged so as to show the essential details of the new system. The triangular flued ovens have proven so successful in actual operation and offer so many advantages that The Koppers Company is recommending their adoption for all future installations.

The triangular flued oven system embodies in principle much more than the change in the shape of the flues, as will be understood from the further discussion. One of the most obvious features of this system, as it has been developed, is that it provides in each wall two separate systems of heating flues. One system consists of the vertical flues facing toward the right with their corresponding horizontal flue, and the other consists of the vertical flues facing toward the left with their corresponding horizontal flue, the two horizontal flues being entirely separate. Both systems obtain their gas supply from a common fuel gas distributing flue or, in the case of producer gas fired ovens, from ports leading from the gas regenerators. Thus, each oven is heated essentially by its own sets of heating flues, which are capable of independent regulation with respect to the flues of the adjoining ovens. This accomplishment is remarkable in that it has been achieved without increasing the width of the oven wall, without increasing the weight of brickwork in the wall, and without increasing the investment for the oven structure. In fact, this seems to be a notable departure from the ordinary rectangular flue system, giving great independence of heating for each

This paper was read before the meeting of the Blast Furnace and Coke Association of Chicago, March 30, 1920.

oven while retaining the present width and the present weight of brickwork and operating with a common gas distributing flue.

Some additional facts regarding the triangular flued system will be assembled here before the advantages are discussed further. The overlapping arrangement of the flues should be especially noted. In present constructions of this system, there are 44 vertical heating flues per wall as against 30 in the ordinary Koppers oven. In other words, these new ovens have 47 per cent more points of gas combustion and heating regulation. At the same time, the face of each vertical flue parallel to the oven wall is wider horizontally than the corresponding face of the rectangular flue. Thus, each wall of the triangular

flued system has 21 per cent more liner brick surfaces; i.e., a 21 per cent greater area for direct rectilinear transmission of heat from flues to oven. There are fewer joints in the wall surface of each oven chamber,—the difference amounting to 22 per cent. Each wall has 38 per cent greater vertical surfaces in the vertical flues than in the rectangular flue construction.

Comparative Nozzle Tests.

The stoppage of a nozzle in one of the triangular flues would be expected to have less effect on the wall temperature and on the appearance of the coke than a similar

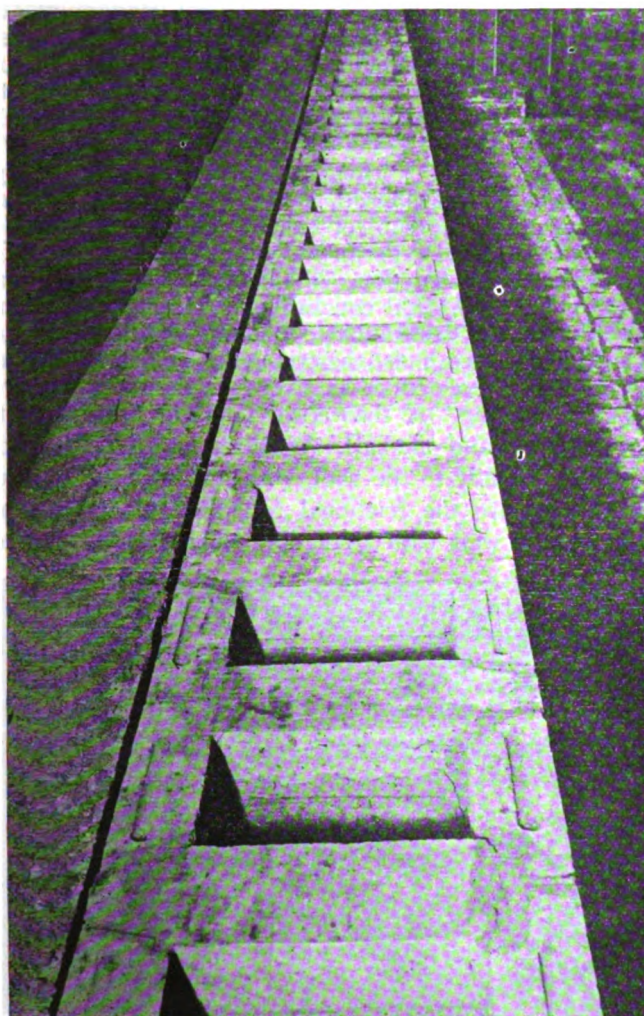


Fig. 1—Rectangular flued oven under construction.

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Independent and Supplementary Flue Heating.

The greater degree of independence of heating from oven to oven that has already been mentioned is, in fact, subordinate to more important benefits. Not only are there two independent heating systems in each wall, but these systems overlap in such a way that, while they are independent in operation, they are supplementary in ef-

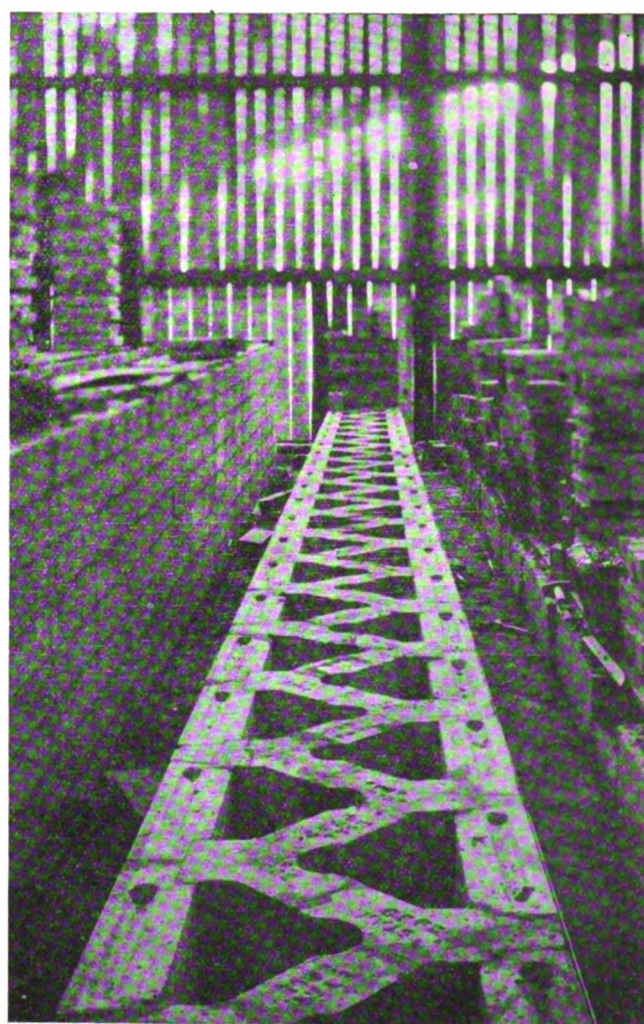


Fig. 2—Triangular flued oven under construction.

fect. On the one hand, by reason of the greater independence of heating, any irregularity in the operation of any one oven has less effect on the adjoining oven; while, on the other hand, in consequence of the over-lapping arrangement whereby the heating effect of each flue is directly supplemented by the adjoining flues, any irregularity in a single flue has less effect on the coke temperature. The greater number of flues in the new type of construction also contributes to the latter desirable result.

occurrence in a rectangular flue, and this is actually the case. A test was made on this point at the plant of the Minnesota By-Product Coke Company, St. Paul, Minnesota, where the first battery of triangular flued ovens has been in operation for nearly two years. This battery consists of five ovens and is operated in conjunction with a battery of 60 Koppers ovens of ordinary type. The plugging of a nozzle in one of the rectangular flues of the ordinary oven produced the appearance of a slight dark spot on the wall when the first charge was pushed, but this spot was hardly dark enough to be noticeable. When the next charge was pushed, the dark spot was distinctly noticeable and when the third charge was pushed, the effect was even communicated to the opposite wall of the

oven. While there are occasional nozzle stoppages in the battery of ordinary ovens, there have, in fact, been none in the regular course of operation of the new ovens, so

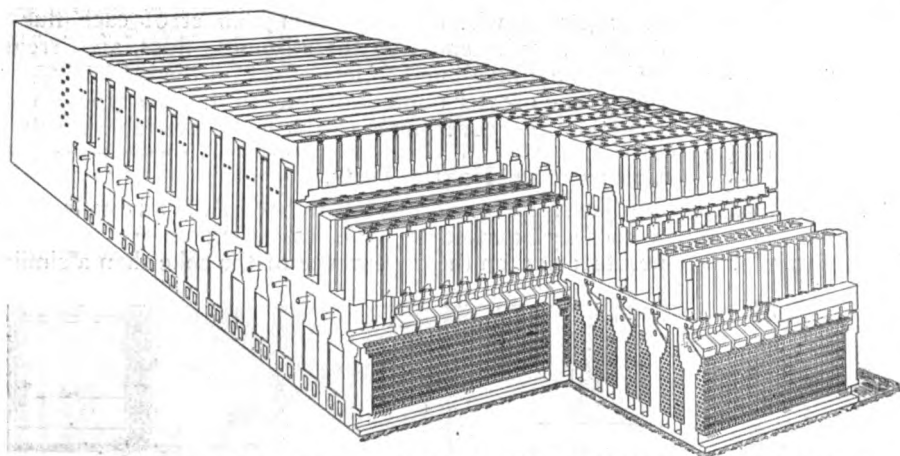


Fig. 3—Perspective view of triangular flued cross-regenerative combination oven.

in order to find out the effect of such a stoppage, one had to be produced artificially. When this was done, there was no dark spot noticeable after 24 hours. After 48 hours, a very slight shade was noticeable in the coke in the neighborhood of the corresponding flue adjacent to the flue having the plugged nozzle. The artificially produced dark spot was not distinct even when the third charge was pushed.

Less Chance for Leakage.

The fact that there are 22 per cent fewer joints in the wall surfaces of each oven chamber naturally means that there is less opportunity for leakage and that the effects

of wear and tear in regular operation are diminished. The joint is naturally the point of least resistance with respect to the abrasive action of the coke, to corrosion by alkalis, and to the action of water and steam from excessively wet coal, and an oven structure having fewer exposed joints is bound to have a longer life. It ought to be remarked, in passing, that the use of coal having more than 7 per cent moisture in coke ovens is not, and never should be, a necessity, and with due regard for the preservation of the coke ovens, ought never to be permitted.

Maximum Strength.

From a mechanical standpoint, the triangular ribbed wall is obviously stronger than the rectangular ribbed wall. The difference has been subjected to an interesting analysis by W. Trinks, Professor of Mechanical Engineering at the Carnegie Institute of Technology, Pittsburgh, Pa. Prof. Trinks has not only examined the subject exhaustively in a theoretical way, but has made experiments with models of the different types of construction. The experiments in each case confirm his theoretical conclusions. He has found that, considering the resistance to bending of the wall held firmly at the two ends, the triangular ribbed wall is experimentally three times as strong as the wall with rectangular ribbing. A theoretical investigation puts the ratio at three and one-half. With respect to a heavy load applied normally to the wall, with not only the end supports, but also the frictional resistance at the top and bottom, the wall with triangular ribbing is 30 per cent

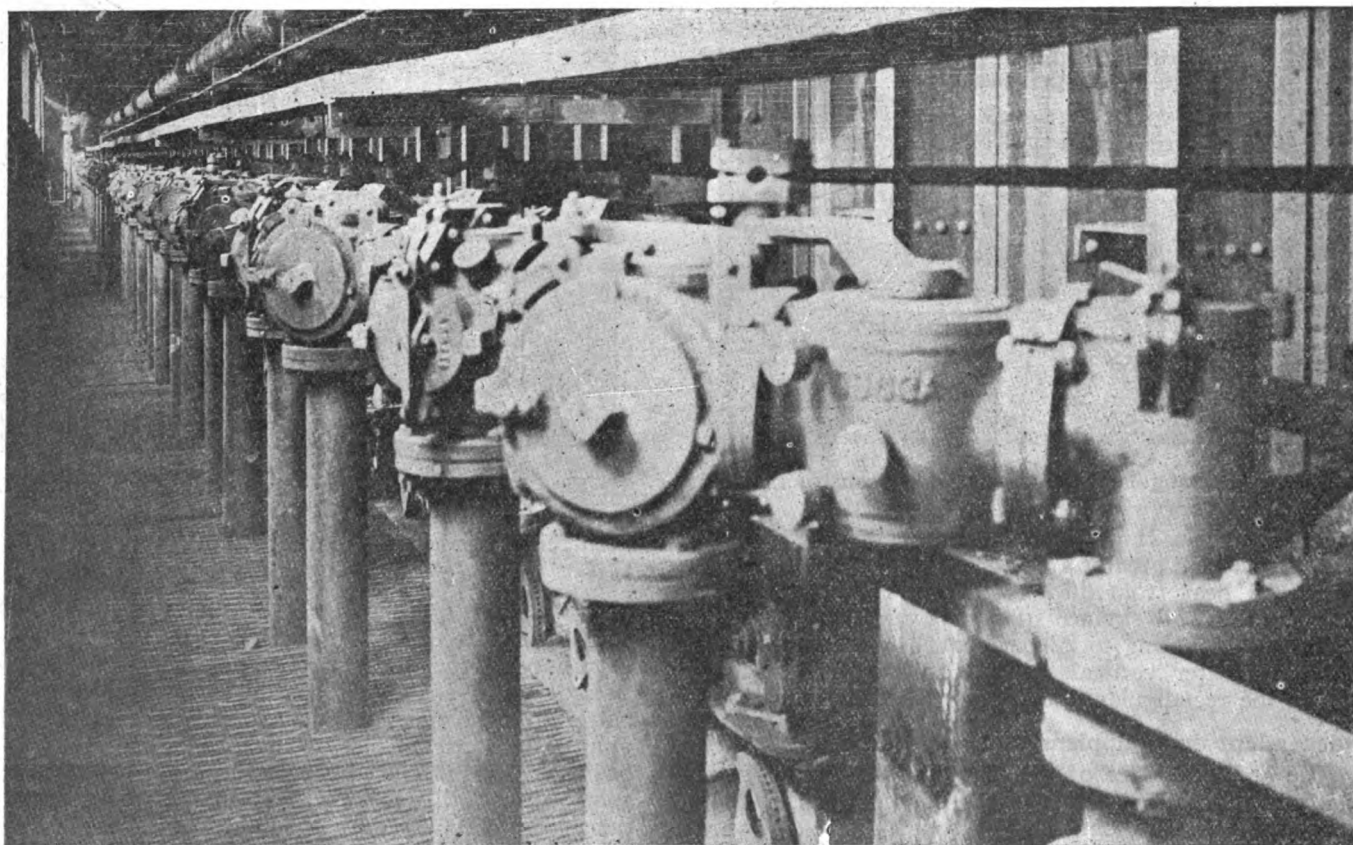


Fig. 4—Gas distributing systems for the Providence ovens. The upper gas main is for coke oven gas while the pipes seen below form connections between the producer gas main and the gas generators.

stronger on the basis of test models and 33 per cent on the basis of theoretical calculation. In fact, the new oven, with its triangular bracing, offers the maximum possible strength for the investment required to produce the maximum heating Efficiency.

Increased Heating Efficiency.

A very prominent advantage of the new system is the gain in heating efficiency that it affords. A little consideration will show how this is made possible. Each oven wall has 21 per cent greater area directly between the flue openings and the coke. There is, therefore, a much greater area through which the heat is conducted directly from the flues to the coke, and the proportion of heat that has to be conducted more or less diagonally through the binder brick is reduced to a corresponding extent. Thus, it is possible to obtain a given rate of coking with a lower average flue temperature than when using rectangular flues. Furthermore, each wall has 38 per cent more vertical surfaces in the vertical flues. This fact is important from the standpoint of heat absorption. Under given conditions of rate of gas combustion and rate of coking,

there will be a greater percentage of heat absorbed and directly utilized in the triangular flued system than in the ordinary system. Tests at the St. Paul plant showed

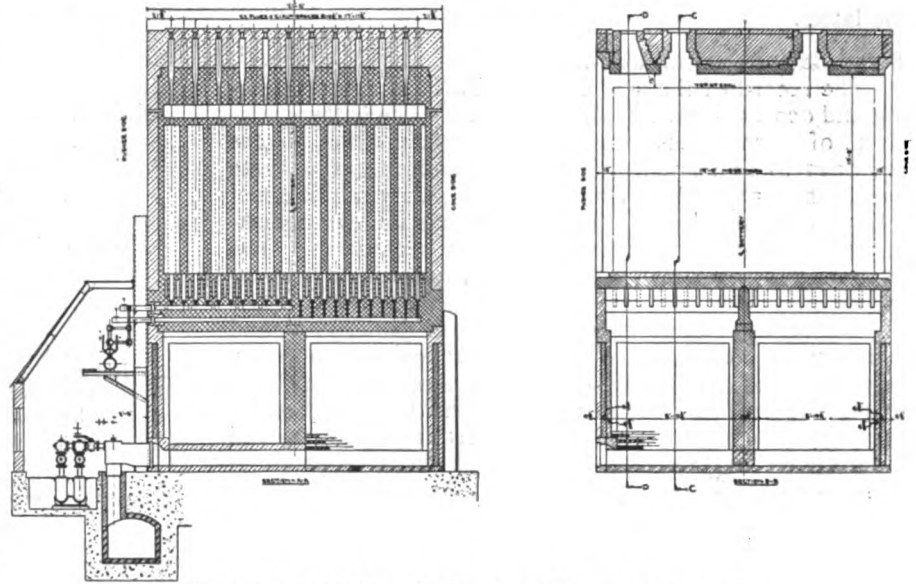


Fig. 5—Sectional drawing of the new Koppers gas oven.

that, for a given speed of coking, the temperature of the hot waste gases entering the regenerators was 100 de-

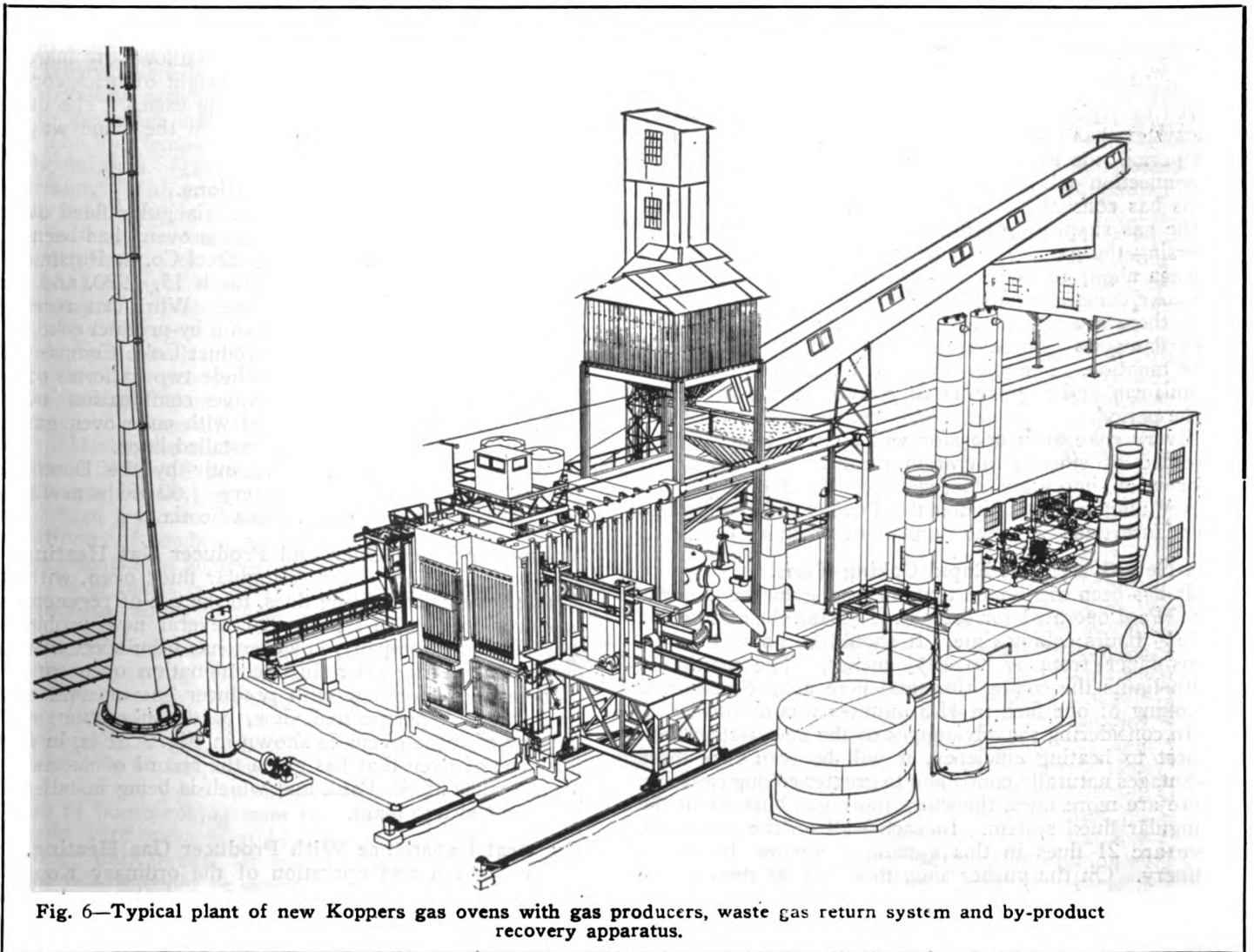


Fig. 6—Typical plant of new Koppers gas ovens with gas producers, waste gas return system and by-product recovery apparatus.

grees F. lower in the triangular flued battery than in the rectangular flued battery, showing a better degree of heat absorption in the flue system of the former than in the latter.

First Battery Installation.

The record of the new ovens at St. Paul is very striking and deserves some description here. The battery consists of five cross regenerative combination ovens equipped to be heated either with producer gas or coke oven gas, each oven having a rated capacity of $12\frac{1}{4}$ net tons of coal per charge. The battery has its own collecting main with arrangements for gas separation. The ovens taper from 17 to $19\frac{1}{2}$ inches and are 9 feet 10 inches high by 37 feet long (inside dimensions).

The battery began its test operation in June, 1918, and has been in continuous operation for nearly two years. It was heated and started in exactly the same way as a battery of ordinary Koppers ovens and was handled by the regular plant operators without requiring any special attention or extra labor. The ovens were operated in series with those of the 60 oven battery and on the same coking time, using a mixture of Elkhorn and Pittsburgh coals in approximately equal proportions, with from 15 to 25 per cent of Pocahontas. In February and March, 1919, a series of tests was made on the new ovens, in the course of which they were operated for some time at a coking time of $13\frac{1}{2}$ hours in order to determine their maximum coking speed. At the beginning of these tests, the usual adjustments of heat regulation were made as in regular operation.

During the subsequent period of a little over one year, there has been not a single change in the nozzles or in the sliding brick settings. Not one nozzle has been removed or replaced, and the interior arrangement of the flue system has required absolutely no attention. During this period, the only actual work that has been required in connection with the heating of the triangular flued ovens has consisted in the ordinary, occasional cleaning of the gas supply pipes and in the regular operation of reversing the gas. The regular coking time has varied between about 16 hours and 24 hours, according to gas and coke demand, and naturally, with changes of coking time, there are adjustments of the main gas valves and stack dampers. These are so simple as scarcely to deserve mention. The temperature conditions now are just as uniform and regular as they were at the beginning of the period.

Every coke oven operator will appreciate what such a record of smooth operation means. The saving of labor is an important consequence. It is obvious that a given number of triangular flued ovens will require less attendance than the same number of ordinary ovens.

The New System on Rapid Coking Time.

It has been mentioned that the triangular flued ovens at St. Paul operated for some time during the test period at $13\frac{1}{2}$ hours coking time. It should be noted that the ovens taper from 17 to $19\frac{1}{2}$ inches. The maximum width limits the coking time and here a maximum rate of coking of one inch in 41.5 minutes was attained.

In considering the advantages of the new system with respect to heating efficiency, it will be seen that these advantages naturally contribute to greater coking capacity. There are more flues, therefore more gas burners in the triangular flued system. In each wall on the coke side, there are 21 flues in this system as against 14 in the ordinary. On the pusher side, there are 23 flues in the former as against 16 in the latter. Such a combination of high capacity for direct heat conduction, efficient heat absorption, and ability to burn gas at a greater number

of points has great advantages where a high rate of coking is desired.

Summary of Discussion of Triangular Flued System.

Having thus considered the merits of the triangular flued oven system it may be convenient to summarize the discussion by classifying the outstanding facts as follows:

1. Durability
 - (a) Maximum strength of wall to resist operating stresses.
 - (b) Fewer joints in oven chamber.
 - (c) Lower flue temperatures for a given rate of coking.
2. Low cost of operation.
 - (a) Less inspection and adjustment of the heating system and, consequently, less labor and repairs.
 - (b) Practically no carbon accumulations, therefore, less labor.
 - (c) Greater heating efficiency.
3. Regularity of coking.
 - (a) Overlapping arrangement of flues.
 - (b) Each oven has practically its own set of heating flues.
 - (c) Greater number of flues.
 - (d) No nozzle plugging.
4. Heating efficiency.
 - (a) More surface for direct conduction.
 - (b) More surfaces for heat absorption in the flue system.
 - (c) Less chance for joint leakage.
5. Greater flexibility of adjustment.
 - (a) Greater number of points of regulation.
 - (b) Double flue system in each heating wall, with cross-regenerators serving each system.

At this point it will be asked what the cost of the new system is as compared with the ordinary Koppers oven. The answer is that the costs are exactly the same. In other words, the important advantages that have just been discussed, have been obtained without any increase in the cost of construction. The weight of brickwork is the same and the work of bricklaying easier. The ovens are heated and put into operation in the same way as ordinary Koppers ovens.

Triangular Flued Oven Installations.

Besides the original battery of triangular flued ovens at St. Paul, a battery of 60 of these ovens has been installed for the Jones & Laughlin Steel Co. at Pittsburgh. This battery began operation March 15, 1920, and has been giving excellent performance. Work has recently been started on the construction of a by-product coke and gas plant for the Chicago By-Product Coke Company at Chicago, Ill. This plant will include two batteries of 50 triangular flued cross-regenerative combination ovens each. The ovens will be heated with coke oven gas at first, but gas producers will be installed later.

A contract has been let recently by the Dominion Iron & Steel Co., Ltd., for a battery of 60 of the new type ovens to be built at Sydney, Nova Scotia.

Triangular Flued Oven and Producer Gas Heating.

The adaptation of the triangular flued oven, with its double systems of heating flues, to the use of regenerated producer gas as fuel presented several new problems. The Koppers Company, however, has been successful in developing a triangular flued combination oven capable of being heated either with producer gas or with coke oven gas. A perspective view, partly in section, of a battery of these ovens is shown in Fig. 3. It is, in fact, this type of oven that has given the record of successful performance at St. Paul, and which is being installed at the new Chicago plant.

Practical Experience With Producer Gas Heating.

The design and operation of the ordinary Koppers combination oven are so familiar and the method of adaptation of the principle involved to the triangular flued oven is so plain from a study of Fig. 3 that it is

considered unnecessary to add any description relating merely to the oven structure and functions. It is well worth while, however, to discuss the results of practical experience with producer gas heating as applied to the ordinary Koppers oven. This practical experience has been gained during the past year at the plant of the Providence Gas Company, Providence, Rhode Island, which has 40 Koppers combination ovens. The ovens taper from 18½ inches in width at the discharge end to 15¾ inches at the pusher end, are 9 feet 10 inches high and 37 feet long (inside dimensions), and have a rated capacity of 11.4 tons of coal per charge. The distance from center to center is 3 feet 6¼ inches. Part or all of the ovens may be operated with producer gas as the demand for domestic gas and for coke varies. For a gas works, this makes an arrangement of ideal flexibility whereby such a plant may serve a wide range of demand. However, the advantages of heating by-product coke ovens with producer gas are not merely confined to such plants as are operated for the gas industry, but deserve careful consideration from the standpoint of the iron and steel industries. It is from this standpoint that the following discussion of the subject is presented.

Advantages of Producer Gas Heating.

There are, in the first place, certain operating advantages that apply to any by-product coke plant heated with producer gas, no matter what its industrial relationship. Then, there are certain economic advantages peculiar to the iron and steel plants. Let us first consider the operating advantages.

With producer gas firing, on account of the absence of hydrocarbons, there is no accumulation of carbon in the gas distributing system. Practically no attention need be given to gas pipes and flues, which means economy in labor. The flue temperatures are easily adjusted and remarkably uniform. There is less possibility of localized overheating. With producer gas, we are dealing with a fuel that is handled in relatively larger volumes than is the case with coke oven gas and no such fine adjustments are necessary with the former as with the latter. Furthermore, any slight irregularities in the rate of gas flow, in the way of adjustment, or in the height of flame, make much less difference in the coke temperature than would result from similar irregularities in the case of coke oven gas. With producer gas, it is a much simpler matter to maintain efficient and uniform heating with a low percentage of excess air than when using coke oven gas. At Providence, the analysis of the products of combustion showed 17 to 18 per cent carbon dioxide with about 1 per cent of oxygen and practically no carbon monoxide. Such a close approximation to theoretically perfect conditions of combustion combined with uniform heating is a remarkable achievement in the use of producer gas. At 14 hours coking time the temperature of the stack gases was about 350 degrees C.

Rapid Coking With Producer Gas.

All of these operating results and advantages have been demonstrated at the Providence plant. The use of producer gas has been found to be excellently adapted to the maintenance of very short coking times, where absolute uniformity of temperature is of the utmost importance. The ovens were operated with straight producer gas at 14 hours coking time for a test period of two weeks and were operated at 14½ hours coking time for a period of four weeks. It was demonstrated that such rates of coking could be maintained regularly and without extra attention. The 14 hours coking time corresponds to a rate of carbonization of one inch oven width at the wide end in 45.4 minutes.

Coke Oven Heating With Producer Gas in Relation to the Iron and Steel Industries.

Turning now to the economic side of the utilization of producer gas for heating by-product coke ovens, operated in connection with blast furnace plants or steel plants, we find that the most important considerations are the following:

1. The value of coke oven gas.
2. Cost of storage and distribution of coke oven gas.
3. The possibility of manufacturing producer gas from cheap fuel.

Heating With Blast Furnace Gas.

At this point, it should be remarked that blast furnace gas is excellently adapted for heating Koppers combination ovens in the same manner as producer gas, and this economic study should include consideration of such use of blast furnace gas.

The economic balancing of the fuels produced and consumed in iron and steel manufacture is of the first magnitude of importance, and an adequate discussion of it would be far too long for the limits of such a paper as this. The subject has been dealt with by the British Association Fuel Economy Committee, whose report has been published in Volume 100 (1919) of the "Journal of the Iron and Steel Institute." The reading of this report discloses many important facts that ought to serve as the basis for improving the general condition of the iron and steel industry in Great Britain; but one gains the impression that there is a little too much of the attitude of justifying these conditions, rather than working aggressively for their improvement. It is, however, interesting to note the unanimous recognition of the advantages resulting from locating by-product coke plants in close proximity to the iron and steel plants which they serve. It is very fortunate for the industries that these advantages have been well recognized and demonstrated in America.

After many years of neglect and inefficient utilization, this valuable fuel has, during recent years, been more and more appreciated. Many steel works need more of it than their by-product coke ovens can supply. The need will, of course, vary with the type and location of plant, the nature of its products, and the amount of reheating that has to be done; but it may be safely asserted that it is an exceptional steel plant that could not profitably use or sell the entire output of gas from its by-product coke ovens, if such were available.

Gas Requirements vs. Coke Economy.

The British association report takes as its main thesis, "That the achievement of the utmost fuel economy of a modern iron and steel works is essentially a matter of the scientific organization and disposition of the plant as a whole with a view to utilizing to the best advantage, in the steel works and rolling mills, the energy in the surplus blast furnace and coke oven gases. This has been shown to be sufficient, not only for converting molten iron from the blast furnace into steel, but also for rolling the resulting ingots into finished steel sections." Closely examined, this does not have the definite meaning that at first sight appears, because of course, the energy in the surplus blast furnace and coke oven gases could be very considerably increased merely by increasing the coke consumption per ton of pig iron, and it is very questionable how far it is wise to go in the way of increasing the consumption of high grade, expensive blast furnace coke for the sake of making additional gas. Many plants, located close to supplies of cheap coal unsuitable for manufacture of metallurgical coke, might do better by operating their blast furnaces to the highest pitch of coke economy and

by supplementing the available blast furnace and coke oven gas with producer gas, either made directly from low grade coal or else made from low grade coke produced from such coal.

Advantages of Conserving Entire Production of Coke Oven Gas.

These are all matters to be studied by making a careful financial analysis of each possibility in connection with the local conditions of each plant. There is, however, bound to be, in each case, a comparison between three principal fuels—blast furnace gas, producer gas, and coke oven gas (supplemented in some cases by coke oven tar). In almost every case, it will be found that, sooner or later, advantage will result from conserving all of the coke oven gas for use in the steel mills or for sale and from using producer gas or blast furnace gas to heat the coke ovens. The equipment required for distributing a given number of heat units in the form of coke oven gas is, of course, much cheaper than that required for the same number of heat units in the form of producer gas or blast furnace gas. The expense of pumping is very much in favor of the former. Where gas producers must in any event be employed to produce supplementary fuel, there may be advantage in using these gas producers to supply gas to the coke ovens, because in this connection they will be in continuous operation, and there will not be the expense of shutting down and starting up the producer plant at week ends. The gas producers operated for heating the coke ovens can consume cheap high-sulphur coal, which has no detrimental effect on coke oven operation, but is unsuitable for steel making on account of the high-sulphur content of the gas produced. Where local conditions favor the sale of coke oven gas, storage facilities may be necessary to take care of the varying load. In many cases, the equipment required for burning coke oven gas is cheaper than that required for producer gas or blast furnace gas.

In the case of plants operated in connection with independent blast furnaces or in connection with steel plants that do not require all of their surplus gas, there are still many opportunities for the sale of the entire output of coke oven gas to supply neighboring industrial establishments, or even for domestic purposes. The growing shortage of natural gas, the increase in the price of coal, and the appreciation of the value of coal gas as domestic and industrial fuel will serve to make such disposition increasingly advantageous.

Various Producer Gas Operations for Coke Oven Heating.

In considering the economic operation of gas producers in connection with by-product coke ovens, several possibilities present themselves and the variety of possibilities, when considered in the light of the potential economic advantages, is one of many arguments in favor of building every by-product coke plant so that producer gas may be used at any time for heating the ovens if desired.

First, the producers may be fed with small sized coke unsuitable for use in the blast furnaces. Here the equipment is simple and comparatively inexpensive, especially with respect to the gas cleaning apparatus. The amount of coke required for the producers is 12 to 14 per cent of the weight of the coal charged into the ovens. This amount may be readily obtained by properly screening the oven product,

leaving a high grade, thoroughly clean coke for the use of the blast furnaces.

Second, where there is available a cheap coal, having fair coking qualities but unsuitable for the manufacture of blast furnace coke, such coal may be coked in some of the by-product ovens delivering, thereby, its by-products and furnishing sufficient coke for the operation of the gas producers.

Third, where there is available cheap low grade coal unsuitable for making blast furnace coke, such material, or lignite, may be used directly in the gas producers.

Fourth, by-product producers may be installed using any coal available. The equipment and operation of by-product producers fits in very well with that of the by-product coke plant and the combination, costing much less than separate plants, offers many possibilities for increased economy and valuable returns. Heretofore, on account of coal values, the employment of by-product gas producers has been more extensive in Europe than in America, and here, with the present appreciation of coal values, their development presents enormous possibilities.

The Kerpely Gas Producer.

The type of producer conspicuous in European practice in connection with by-product coke ovens and elsewhere is the Kerpely producer. The Koppers Company controls the American patent rights on this type of producer and is actively adapting it to American conditions for its by-product coke oven operations and in connection with by-product producer plants. The next few years will witness much important progress along this line.

Economic Changes Favoring Coke Oven Gas.

The situation is that, on the one hand, the developments of the gas producer, whether using coke or coal in connection with by-product coke ovens, together with the successful and advantageous application of producer gas to oven heating, are such as to offer the strongest inducements for this method of heating; while on the other hand, the demand for high grade gas is increasing so that every by-product coke plant in the country is, sooner or later, going to be required to render available every cubic foot of coal gas that it makes.

It is eventually going to be considered rank inefficiency for any plant to use this valuable gas for the purpose of heating its ovens, which purpose could even be better served by lower grade gas. These requirements are going to be brought about by the increasing shortage and cost of good coal, the increasing shortage of natural gas and fuel oil, and by the advantages of coke oven gas over lower grade gases from the various standpoints discussed. In the face of this, it is plain that every new battery of by-product coke ovens built in connection with a steel plant or blast furnace ought to have provision so that, at any time, producer gas equipment can be added to the plant and so that the ovens can be heated either with this gas or with blast furnace gas.

The Combination Oven and Its Relation to Future Developments.

Suppose that, in the case of a given projected plant, it might possibly appear, on the face of present financial returns, that there would be no marked present gain from the installation of gas producers in connection with the coke ovens. Nevertheless, as-

suming that the life of a battery of modern coke ovens is from 10 to 15 years and, in view of the great economic and engineering progress possible in the life of such a plant, one should hesitate before committing himself to building plain coke ovens, which would practically require rebuilding before they could use producer gas economically. The use of producer gas or blast furnace gas might well be advantageous a few years hence, if not now. The building of combination ovens is, in effect, providing insurance against future contingencies at relatively low cost and with promise of large returns.

Height of By-Product Ovens.

In the recent work of by-product coke oven engineers, some attention has been devoted to the prob-

lem of what is the most suitable height for coke ovens operating with maximum efficiency. This is important from the standpoint of investment required for a given plant capacity. The width of the oven is determined by technical considerations, chief of which is the effect of this factor upon the quality of the coke. It has been shown that increase of length is practical and may be of advantage; but, from the standpoint of economy of investment, greater proportional advantages evidently result from increase of height.

The height of the standard Koppers oven was, for a number of years, 9 feet 10 inches (measured from top to bottom of the chamber). Some time ago, however, 30 ovens about two feet higher than this were put into operation for the Indiana Coke & Gas Co.,

Utilizing Blast Furnace Gas for Power

Power Production Data From Blast Furnace Fired Power Plant—Heat Balance—Explanation of Equipment Included in Blast Furnace Steam Generating Plant.

By F. H. WILLCOX.

Secretary, Freyn, Brassert & Company.

NOT to go back too far in the development of types of boilers and gas combustion arrangements at blast furnace boiler plants, it is remarkable to realize that in one decade the characteristic of the boiler unit has changed from one of 2,500 to 5,000 heating surface, equipped with Spearman type burners and hand grates, to a unit of from 7,000 to 12,000 heating surface provided with efficient mixing burners; that the steam characteristic has changed from 160 lb. and no superheat to 225 lb. and 125 degrees superheat and higher; that already the elimination of hand firing for auxiliary fuel requirements is accomplished; and that the solitary steam gauge is replaced with elaborate indicating and recording instruments for steam, pressure, temperature and volume control, for draft control, and in some cases combined air and gas or stoker control synchronized with damper control.

This development indicates the realization of the perhaps earlier theoretical conception of the power possibilities latent in gases available from a blast furnace and the determined effort made in the face of adverse factors to apply developments in central power plant design to blast furnace boiler houses.

A brief review of adverse factors which have retarded this development may not be out of place. First of all, the concern of a power plant is to make and sell power, consequently the cost of power and its regularity of supply are the two vital points of scrutiny both in design and in operation. At a blast furnace or steel plant, steel (or iron) is the product. Its quality, cost and regularity of production are the points of scrutiny. Steam supply primarily has had to be ample, regular and secure; not necessarily economical in the strictest sense. Even five years ago, out of a total cost of production of pig iron of \$11.25, steam cost but \$0.28 and with a base price of Pittsburgh coal at \$1.25, economies resulting from direct fuel or gas credit savings were obviously small, and compared to regularity of supply, of little appeal.

Moreover, the operator—concerned primarily with regularity of steam supply—was adverse to any pro-

gram which, in the face of a varying fuel gas supply, imposed a load on the blast furnace boilers which corresponded closely to their full gas fuel supply and theoretical potential steam generation. A specific illustration or two will show the condition. At a furnace operating at the rate of 430 tons per day, a gas flow test was made in the boiler house gas main. The test was by means of thermometer and Pitot tube and was of three hours duration between casts. A maximum of 30,930, a minimum of 21,930 and an average of 28,120 cubic feet of gas per minute was shown. This corresponds to 3,460 Bo. hp maximum, 2,390 Bo. hp minimum and 3,070 Bo. hp average. There was therefore a surplus of 390 Bo. hp above and a deficit of 680 Bo. hp below the Bo. hp which could be carried as an average operating condition. From this it is very easy to see the reason for the condition which so frequently distresses the general office and the steam engineer, i. e.: alternate deafening blowing-off of safety valves to be later followed by tremendous exertion in hand firing with its accompanying prodigious clouds of smoke.

It may also be of interest to show a more careful study on gas flow. In this case the furnace was working normally, i. e.: during the day it drove sometimes a little fast, sometimes a little slow, occasionally it would get a little stiff for some moments, then loosen up, and the gas flow varied accordingly. Pitot tube readings were taken at one-half hour intervals. Pressure, gas analyses and temperature observations were also taken. It may be assumed to be accurate and representative of what may be encountered. The amount of gas per minute throughout the day, at the above half-hour intervals, was as follows:

Read across—							
38,000	34,200	47,800	34,200	34,200	32,500	27,000	
36,000	30,000	36,000	38,000	32,500	32,000	30,600	
38,000	34,200	34,200	30,000	38,000	38,000	41,500	
38,000	34,200	36,000	36,000	36,100	38,000	48,500	
36,000	32,500	30,000	39,000	27,000	34,200	38,000	
36,000	36,000	40,100	27,000	38,000	32,500	34,200	
42,500	45,000	45,000	39,000	34,200	27,000		

This is all the gas from a single furnace, gas volume reduced to 62 degrees and 30 inch hg.

It goes without saying that in neither case, and the writer considers them representative, could a uniform steam load be carried unless the gas to the stoves was continually regulated to give a constant gas pressure at the boiler house. This is an expedient that, as a rule, involves too much hazard to quality and cost of iron to obtain much consideration.

It will be apparent, from the viewpoint of fluctuation of gas supply to the boilers, why the operators have preferred to preserve a conservative course which would surely furnish an adequate supply of steam at reasonably constant pressure and volume, at the expense of realizing a maximum steam generation from gas. In other words, having a maximum of 3,400, a minimum of 2,400 and an average of 3,000 Bo. hp available from a 430-ton furnace, it has been preferred to realize something perhaps even less than the average in the shape of a steady steam load, to hand-fire during repeated slack gas periods, to blow-off steam during heavy gas periods, simply to realize a steady steam pressure to blowers and pumps.

It is evident, when one considers imposition of heavier loads, that the heavier the load carried on the basis of the average furnace gas flow, that the coal and ash handling charges become increasingly larger, coal firing becomes increasingly more sudden and strenuous, cleaning of grates becomes more and more of a problem, and most detrimental drops in steam pressure occur with increasing seriousness and frequency. Therefore, gas credits for steam supplied to other departments have been sacrificed to the benefit of steady load, especially with low base coal prices. The identical circumstances also disclose the reason why it has been preferred to have a liberal number of boiler units run at an overload not greatly in excess of builders' ratings. Such an arrangement makes available more grate units for firing and for cleaning, and moreover usually gives a greater water volume to flash into steam as the pressure drops.

The alternatives to carrying a moderately low load are:

1. Running all boilers on high rating with mixed gas and hand firing.

Advantages:

Utilization of all gas.

Going coal fire to handle gas fluctuations.

Objections:

Low efficiency of fuel.

High cost of surplus steam to other departments.

2. Running a proportion of all boilers on gas at high ratings, with coal fired boilers segregated.

Advantages:

Utilization of all gas.

Good efficiency in use of gas.

Going coal fires to handle gas fluctuations.

Objections:

High cost of coal fired surplus steam.

Large number of boiler units required.

3. Running all blast furnace boilers on gas, with steel plant boiler house balancing high and low gas flow rates.

Advantages:

Good efficiency in gas firing.

Low labor cost for surplus steam.

Objections:

Occasional low steam due to combination of one or more furnaces off with poor gas from others.

Condition infrequently very serious.

4. Running blast furnace boilers on gas, corresponding to highest blast furnace boilers on gas, corresponding to highest gas flow rate, with blast furnace gas deficiency made up by auxiliary coke gas oven or tar firing.

Advantages:

An ideal combination both for high rating and efficiency.

Objections:

Higher auxiliary fuel costs, though not necessarily higher costs per Bo. hp considering low labor charge.

Oil costs for similar uses usually prohibitive.

5. Concentration of gas firing on certain boilers, with excess and variable load carried by stoker fired boilers at same house.

Advantages:

Equally as good an operating proposition as Option No. 4 and lower fuel costs.

Objections:

Higher installation costs.

Larger number of boiler units required.

6. Equipment of all boilers both with stokers and gas burners.

Advantages:

Equally efficient gas and coal combustion as with Options Nos. 4 and 5.

Ability to carry continuous high rating on boiler with smaller number of units.

Objections:

Rather high unit cost.

The latter of the above methods will permit carrying such combined furnace and other department steam loads so that the full amount of Bo. hp available from furnace gas may be realized, and in addition, additional evaporation may be obtained cheaply from stoker equipment so that a very high load factor may be carried on any given installation of electrical generators. Certain methods permit better efficiencies to be realized from gas than others. The writer's experience has indicated that in the choice of methods for carrying steam loads lies the practical realization of full development of potential steam from blast furnace gas supply, and also the secret, if any, of high boiler efficiency on gas. Pre-mixing burners with adjustable air supply, draft control, attention to baffling, air tightness of settings, systematic tube blowing and turbinizing, with their indisputable possibilities of high efficiencies have repeatedly shown failure to realize in a practical way effectiveness in high efficiency and overload from available gas when they have been handicapped by combined hand firing of coal and combustion of gas on the same set of boilers, or by equipment limitations relating to realization of continuous steam supply constantly corresponding to periodic maximum gas flow.

To develop a tangible view of the possibilities in the way of steam generation and power available from a furnace burning 1,100,000 pounds of coke per day, or a production of 550 tons of iron, the power production is shown below:

Gas per ton iron	142,800 cu. ft.
Less 5% for gas loss, radiation and ladle uses	135,660 cu. ft.
Dry gas per minute	51,800 cu. ft.
Total heat per lb. of gas at 250°, 30" hg., 40 gr. moisture	1,313.8 Btu.
Equivalent heat per cu. ft. at 62° and 30" hg.	101 Btu.
Total heat available per minute	5,250,000 Btu.
Wind volume and heat	42,500@1,300° F.
Gas used at stoves	1,440,000 Btu.
	27½%
Gas available at boilers per minute	3,810,000 Btu.
Bo. hp available	4,800 Bo. hp
Steam available	146,000 lb.
Water pumped for furnace and furnace auxiliaries, boiler feed, turbo blower, cooling, condensers, and miscellaneous	28,000,000 gal.
Steam requirements: Blower, condenser, dry air pump, service water, condensation and losses, boiler feed and heating	70,000 lb.
Available for power	76,000 lb.
Available power	5,400 kw
Power load: Metered. Pumping.....	400 E. hp 400 E. hp

Skip transfer and scale car....	135 E. hp
Bridge and unloader	450
Pig machine pouring crane	
Cast house and Eng. crane	40
Coke breeze coal and ash.....	15
Compressor	60
Feed water plant	20
Lighting and miscellaneous ...	100
Total, including pumping	800 E. hp
Total kw	1,200 E. hp
Total surplus	900 kw
Average steam load	4,500 kw
Maximum steam load during	
high pressure at furnace ..	146,000 lbs. = 4,800 Bo. hp
Minimum steam load during	
cast at furnace	156,000 lbs. = 5,100 Bo. hp
	124,000 lbs. = 4,100 Bo. hp

From the tabulation it is clear that the available gas will carry an average load of 5,400 kw. During gas flow fluctuations or at cast time or furnace stops when the gas fails, this amount of power must be kept coming if other departments are to rely upon it, and more especially must it be kept coming should the vital pumping equipment be carried by the furnace generators.

Assuming a battery of six 1,000 hp boilers, with two operating stokers, it is apparent that two stoker fired boilers will nicely carry the load at furnace stops, and that they will be available for come-and-go firing between casts. This is, however, a very small load factor to be imposed on expensive equipment. This is particularly true if it be borne in mind that to realize this partial load factor three boilers must be equipped with stokers to allow for boiler repairs and cleaning. Similarly, to take care of gas four boilers must be equipped with burners. The house, therefore, consists of one stoker fired boiler, two combined gas and stoker boilers, and three gas boilers. This house, as remarked, will only carry a steady load of 5,400 kw over cast. If the low point of the electric load factor can be figured to usually coincide with cast time, 6,500 could be carried between casts at the expense of about 550 average Bo. hp on the stokers.

At the addition expense of equipping all boilers with gas burners and stokers, and with five operating, the blast furnace boiler house could carry a steady load of 13,500 kw, the stokers operating at 175 per cent rating over casts, and at 95 per cent rating between casts, carrying 8,750 Bo. hp over casts and 9,450 Bo. hp between casts. This is an ideal layout, using a good constant load factor on expensive stoker equipment, utilizing the boiler equipment to full advantage, and centralizing power generation for an entire integrated steel works and furnace plant at one central power station with minor increase in labor over a power plant realizing only the average potential power from furnace gas, and at probably less gross operating expense than when only a portion of potential power is attempted with auxiliary hand firing.

To carry the overloads on rating mentioned involves a high draft loss through the boiler, consequently a stack of liberal height and cross-section and clean gas.

There is a larger volume of gases of combustion to be handled per Bo. hp with blast furnace gas than with stoker firing of coal. (See table above).

The consequence is that boiler baffling as well as stacks must be particularly designed if these high ratings are to be carried with exceptional efficiency on combined gas and coal.

Coal Firing.		Gas Firing.	
Efficiency	72 %	Efficiency	70 %
CO ₂	12.2%	CO ₂	21.2%
Lb. coal	3.5	Cu. ft. gas	460
Lb. gases combustion	60	Wt. gases combustion	73
Cu. ft. gases combustion	750	Cu. ft. gases combustion	900

With stacks and boiler baffling carefully designed and with clean gas and good boiler feed water, there is nothing to prevent a battery of six 1,000 hp boilers being equipped with both stokers and blast furnace gas burners, and when five boilers can be continually kept in operation producing 9,500 Bo. hp with gas and coal firing. With stoker firing, as contrasted with hand firing, gas can be used at exactly as good advantage as in an exclusively hand-fired boiler. Such an installation is working satisfactorily. The stokers run at 100 per cent boiler rating when the gas is on and at 200 per cent boiler rating when the gas is off. Such an installation is always worthy of consideration with an existing steel plant when there is already a heavy electrical load pull.

It is interesting to note that a good furnace plant recovers in entirely salable surplus power, 3 per cent of all heat energy charged in coke.

A summary of work effected at a complete blast furnace plant in the shape of a heat balance may be of interest:

	Per cent	Heat
(1) Heat charged in coke	100	575,000,000 Btu.
(2) Heat retained in furnace ...	45.0	255,500,000 Btu.
(3) Heat used in hot blast	10.0	60,500,000 Btu.
(4) Heat lost at stove chimney..	4.5	26,000,000 Btu.
(5) Heat lost at boiler chimney ..	12.	69,000,000 Btu.
(6) Heat used at blower	1.	6,000,000 Btu.
(7) Heat used at generator	3.	18,500,000 Btu.
(8) Heat used at pumps and		
miscellaneous	0.2	1,200,000 Btu.
(9) Heat lost in condensed and		
exhaust steam	24.3	138,300,000 Btu.
Heat usefully applied: (2), (3), (7) and (8)	58.2%	
Heat lost: (4), (5), (6) and (9)	41.8%	

The heat usefully applied in furnace, hot blast stoves and boilers is 83.5 per cent, which, outside of the steam use, indicates a remarkably efficient "heat engine."

The reader thus comes to the point of how the power generation is to be realized. The answer comes down to about three points, and analyzing them, it is found in stove practice, boiler practice and power plant practice.

At the stoves the amount of gas shown consumed was based on 70 per cent stove efficiency. To obtain this there will be required a ratio of about 6.5 square feet heating surface per cubic foot of blast per minute, or 280,000 square feet of heating surface in a total of three or four stoves. There is also required a good pre-mixing gas burner for the stove. Next there must be a butterfly regulating valve and a "U" tube connected to the gas box on the burner side of the butterfly valve. This "U" tube can be filled with sulphuric acid, specific gravity about 1.6, to prevent freezing. The burner air valve should be set for say 10-inch pressure in the "U" tube by means of analyses of chimney gases in conjunction with use of highest heats practically carried. Thereafter the stove tender must carry gas pressure at the burner at the fixed pressure determined as sufficient for highest heats. He must not tamper with the fixed position of air valves of burner. This may meet the objection that

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it is not practiced; the answer is that it works and the practice is being introduced into additional plants.

To meet varying heat practice it is required that an indicating or recording pyrometer be placed in the chimney valve. The average stack temperature of a stove performing on the above basis will be 500 degrees F., starting in at 300 degrees and the stove going off blast at 650 degrees. The burner being adjusted for a gas flow rate corresponding to say 1,300 degrees heat on 42,500 wind, all that remains to be done is to take the stove off whenever the stack temperature reaches 650 degrees. This means that the brickwork is saturated with heat corresponding to 1,300 degrees in blast for one hour. If less blast temperature is carried the stove will be on gas a shorter period; if more, it will be on gas for a longer period.

This practice gives exceptional analyses of stack gases, as high as 23 per cent to 24 per cent CO_2 , maintained indefinitely. Variations in quality of blast furnace gas may be disregarded. Analyses should be checked frequently and burner air valves adjusted if necessary. On this basis a stove of good capacity and construction will give a maintained efficiency of 70 per cent on clean gas.

In the power house, builders' guaranties can be and are maintained within 8 per cent. This relates to steam consumption, horse power and kilowatt basis, guaranties. It comes down first to maintaining vacuum, and with the supply of water usually available or even with re-circulated spray pond water, vacuum is very largely a matter of tight exhaust lines, maintenance of steady steam pressure and superheat, and good efficiencies of dry air pumps.

Steam flow meters to turbines are necessary checks against good maintenance of builders' equipment guaranties.

Steam lines, of course, must be kept tight; traps must above all be given periodical and regular inspection; blow-off lines kept tight, and feed water heater kept clean. Feed water treatment must be maintained at a point where a reasonably low hardness is obtained at the expense of not too great a causticity and alkalinity which might cause priming.

In the boiler house attention must be directed to tight setting and baffling, clean tubes, inside and out. With these essentials fixed there remains the problem of burning the fluctuating gas supply at the burners at high efficiency and at the same time there remains the question of balancing the fluctuating gas load with stoker firing.

First, in regard to gas, unless there are a number of furnaces on the line, steady gas pressure cannot be obtained. To burn the gas efficiently the draft must be regulated so as to keep approximately balanced pressure in the combustion chamber for all gas flow rates, or for combination of stoker firing and gas combustion rates. As a manual job, this is nearly impossible. Automatic draft regulators are, however, practically worked out and can be applied. Certain types of burners can be provided with differential pressure regulators which will admit varying amounts of air corresponding to the gas flow, and this is as good as regulating the draft.

More expensive equipment is to install a fan which will supply air to the gas burners in proportion to the gas pressure at the burners. This is more positive insurance of regular combustion than can be obtained with draft regulators. With a house where stokers are installed throughout in conjunction with gas

burners, the fans installed for the blowers, with some augmentation in capacity, can be used for the positively regulated air supply to the burners.

Similar combinations can be worked out for use of blast furnace gas in conjunction with firing of powdered coal, although at high unit costs.

Regardless of equipment installed, it is a fact that a difference of 10 per cent or more in power plant efficiency is within the control of the engineer in charge. The efficiency is in proportion to the vigilance with which he maintains the recording instruments and the constancy with which he keeps himself personally familiar with the actual performance and condition of the power plant units and the supervision that he gives to the men on watch at night as well as to those on the day turn.

Such a boiler house as has been developed is one that will realize a maximum of load on the equipment and utilize both gas and coal fuels at highest efficiency. It is a house which will require as exacting supervision as a central station selling power, but it will make as much and probably more money for the steel plant as the power station will for its owners, and moreover, dispense with a considerable labor force and insure steady steam for blowing and power for all uses.

Such a house would be unwarranted when fuel prices were low, but when, on the contrary, they are high and will probably remain high, this character of plant demands consideration.

However, should fuel and labor costs continue to advance, or even to hold their present level, it is not in the least improbable that there must come a reversion to gas engine blowing and power generation, even in districts where at present coal costs have made the question entirely to the advantage of steam power and blowing.

EDITOR'S NOTE—The following comment of S. K. Varnes in discussing K. Huessner's paper which was read before the A. I. M. E. meeting in February, 1916, may be of interest in connection with this paper:

We have been keeping operating records for practically all of the four years since we installed feed-water meters and have found these records invaluable. We keep segregated costs of the different operations. We have adopted as our unit of calculation 1,000 lb. of water evaporated, because this requires no conversion from our meter readings and enables us to compare not only our boiler efficiency from month to month but our repair cost items as well. We also keep a chart on which is plotted the monthly average boiler horsepower obtained per ton of pig iron per day. This basis of measuring efficiency is different from the one advocated by Mr. Huessener, and I am inclined to think that his is better, because alongside of the first curve we have to plot a second showing the fuel ratio in the furnaces, in order to make the first curve really intelligible. If we were starting anew we should probably adopt Mr. Huessener's suggestion.

I might say, for the benefit of those who have not studied the problem as deeply as we have, that most of the trouble we have found with air infiltration is with infiltration through cracked brickwork and through joints between the brickwork and steelwork. If the cracks and joints are carefully cared for, the leakage through a well-built wall is almost negligible.

Boiler Feed Water Purification

Purification of Feed Water Described as a Distinct Function Which Is Best Carried Out Independently of the Boiler Auxiliaries—Analysis Showing Possibilities of Proper Treatment.

By M. F. NEWMAN,

Manager, Water Purifying Department, W. B. Scaife & Sons Company.

THE development of the steam boiler to operate at high rates of evaporation as well as higher pressure has resulted in a much more rapid accumulation of the impurities in the water in the boilers. The evaporation of water and of water only, as expressed by the chemist's formula H_2O , occurs in the generation of steam. Very few of the natural water supplies are of such purity as to permit of the concentration occurring without scale or sludge accumulation that seriously interferes with the efficiency and the durability of the boiler.

Feed water supplies available at present are, as a rule, of worse quality than those in use in the earlier days of steam boiler operation. This condition is due to the pollution of streams by manufacturing waste, coal mine drainage, and deforestation. As a result of deforestation there is quick drainage after rainfalls which introduces a large amount of suspended matter.

The great differences in the amount and kinds of suspended and soluble impurities in water make impossible the application of any simple expedient for purification. The seasonal and daily changes in water in the same stream often vary through a wide range. Usually when streams are full and the water very turbid, the soluble impurities are very much lower than when streams are at ordinary level; and, on the other hand, when streams are extremely low the soluble impurities are relatively high.

Keeping in mind the various sources from which impurities get into water supplies and the changes constantly taking place in the relation between the soluble and suspended impurities, it becomes apparent that to successfully purify water from all sources a method must be employed that will standardize the water, regardless of the sources of supply or seasonal changes, and to maintain an absolute uniformity in the purification so that the effect of evaporation in the boiler will not cause scale nor the accumulation of precipitates and other impurities that cause foaming.

The effect of the evaporation of the water into steam is to constantly increase the amount of soluble impurities in the water in the boiler. If lime and magnesia enter the boiler in soluble form, the effect of the concentration is to precipitate the lime and magnesia. The amount of these precipitates is in direct ratio with the volume of water being evaporated and the amount of soluble substances carried in the feed water. In these circumstances, it follows that any variation in the amounts of silica, lime and magnesia directly affects the total amount of impurities in the water from which steam is being evaporated.

The rational method of purifying boiler feed water is to remove the soluble scale forming substances from the water before it enters the heater, feed lines and boilers. This purification should include the removal of all permanent hardness and the reduction of the carbonate hardness to a minimum of approximately 1 grain per

gallon, so that the water is perfectly clear and the total of incrusting solids, including silica and the compounds of lime and magnesia, will not exceed 2 grains per gallon.

Feed water thus purified contains no substances that will react under the influence of heat and concentration to cause corrosion, and scale does not form in the absence of permanent hardness in the purified water. The small amount of silica, lime and magnesia left in the water is of such character that when precipitated in the boiler only a slight sludge is formed. This sludge can be kept at a minimum by proper blowing down and periodic changes of water in the boilers.

In many power plants, warm water runs to waste on account of the oil that it contains. The removal of oil and grease, including emulsified oil from the condensate, can be accomplished concomitantly with the removal of hardness and suspended matter.

To properly soften and purify feed water is a much more difficult process than it is generally understood to be, because the amounts of impurities that have to be removed are so small in relation to the volume of water: Five grains per gallon of impurities in water are less than one-hundredth of 1 per cent; 20 grains per gallon are less than four-hundredths of 1 per cent. The average of the scale forming solids in solution for water from supplies generally in use for boiler feed would approximate 15 grains per gallon. It is, therefore, apparent that work connected with the purifying of boiler feed water deals with extremely dilute solutions. This, with the variations in the quality and quantity of the water used, calls for extreme accuracy of treatment.

The removal of scale forming impurities in such dilute solutions necessitates the establishment of one or more constants before the accuracy required for adequate treatment can be obtained. The constant of primary importance is a fixed volume of water upon which to carry out the complete process. The constant of second importance is the introduction into the fixed volume of water of accurately determined weights of reagents of definite strength and known reaction values in the water under treatment. With two such constants established, the mechanical features must be coördinated so as to include the following:

Proper mixture of the reagents with the water.

Accelerated chemical reaction by mixing the sludge of previous softening throughout the water under treatment.

Complete chemical reaction by having a sufficient volume of water under treatment to insure time for all the necessary reactions to take place.

Rapid sedimentation by having the precipitates weighted by the sludge of previous precipitation.

Perfect clarification by efficient filtration.

An automatic device, to adjust the quantities of reagents to the impurities of various kinds in water, has not been invented. The difficulties in the way are due to the fact that the operation of any automatic device is dependent upon the volume of water. While the volume

may be reduced to a constant, the impurities within the constant volume vary through such wide ranges that an automatic feeding device cannot compensate with reagent solutions for the changing amounts of impurities within the fixed volume.

The relation of an automatic reagent feeding device to the variations in impurities to be removed becomes more apparent when the volume of solution containing fixed quantities of reagents is compared with the requirements per gallon of impurities to be removed from the water. As an example, assuming the water under treatment with an automatic reagent feeding device, the water normally containing 6 grains per gallon of permanent hardness and 4 grains per gallon of temporary hardness, a change of 1 grain per gallon in the total hardness would mean a 10 per cent increase or decrease in the volume of solution to be supplied. If the quantity of reagent solution is held constant for such periods as 8, 10 or 12 hours, then the accuracy required to keep the softening exact places an undue responsibility upon the operator, and in practice it results in a continual search for the proper volume of reagent feed to meet the changing quantities of impurities in the water and the changing values of the reagents themselves.

All chemists will agree that to insure complete precipitation the addition of the reagents must be exact with a slight but carefully controlled excess and that they must be thoroughly mixed with the water. They will also agree that the commercial reagents such as caustic lime, caustic soda, soda ash, etc., will vary in purity, and that using these cheap reagents to remove the various salts of iron, lime and magnesia from the complex, dilute solutions calls for a very accurate method of control and a wide experience with different waters. The time to be allowed for the completion of reactions is a question of vital importance, and temperature is also a factor in the time to be allowed.

The amount and nature of impurities in the water is also a factor in the time to be allowed for reactions and precipitation. In some waters, at atmospheric temperature, the water after treatment has settled perfectly clear after one hour; in other waters in the same condition with the same type of apparatus, this condition is not obtainable until after two and one-half hours; and in some special cases four hours.

Each water presents a specific problem that has to be worked out from the analyses, experimental data and the known results in practice with water of similar characteristics. There is a vast difference between the extent of softening obtained in many plants, due to improper design, and that which is obtainable with properly designed and operated apparatus.

In general, it is desirable to soften feed water before it is heated, although where condensing equipment is in use, the tail water at a temperature of approximately 110 degrees is frequently available.

Any water supply at atmospheric temperature or at the temperature of condenser discharge, can be economically softened and purified for the removal of suspended matter, oil, free acids, iron, lime and magnesia, so that the total of incrusting solids will be less than 2 grains per gallon and the hardness, due to the remaining calcium and magnesium, will be reduced to less than $1\frac{1}{2}$ degrees. This can be done uniformly and regardless of the source of supply from which the water is obtained.

The following analyses show what is accomplished with properly designed and operated equipment, treating water within the range of seasonal temperatures:

The foregoing analyses illustrate the standardization of purified water for boiler feed. It will be noted that,

	Incrusting Solids in Raw	Incrusting Solids in Treated*	Hardness in Treated†	Suspended Matter
Wells	13.03	1.68	1.4	None
Wells and Genesee River..	8.80	1.73	1.15	None
Cuyahoga River	13.67	1.85	1.44	None
Surface Reservoir	16.15	1.82	1.20	None
Cuyahoga River	14.99	1.67	1.00	None
Wells	25.76	1.92	1.40	None
Monongahela River.....	9.29	1.48	1.10	None
Toledo City Water.....	16.16	1.48	1.10	None
Ohio River	6.32	1.78	1.4	None
Mahoning River	11.18	1.66	1.35	None
Miami River	18.54	1.48	1.10	None
River Bk. Wells (White R.)	17.38	1.74	1.30	None
Schuylkill River	8.41	1.76	1.40	None
Spring River	13.97	1.52	1.00	None
Monongahela River	10.08	1.27	0.95	None
Allegheny River	5.64	1.84	1.62	None
Genesee River	17.81	1.86	1.69	None

*Incrusting solids in treated = calcium carbonate + magnesium hydroxide + silica.

†Hardness in treated = calcium carbonate + magnesium hydroxide as equivalent calcium carbonate.

regardless of the source of supply or the amount of incrusting solids in the raw water, after purification, the variation in the hardness is approximately $\frac{1}{2}$ grain per gallon and that the total of incrusting solids is approximately the same. This is of vital importance in that it directly affects boiler operation, for with the feed water thus standardized and the same result uniformly obtained, the operation of the boilers with reference to blowdowns and water changes can be definitely worked out for the evaporation factor at each plant.

The degree of softening indicated by these analyses represents a condition of reduced or sub-normal solubility of the calcium and magnesium compounds remaining in the water, and as a consequence there are no after deposits in pipe lines, heaters or economizers, and the sludge resulting from the concentration occurring within the boiler is a known factor.

It is not generally recognized by boiler plant operators that a difference of 1 or 2 grains per gallon of incrusting solids may differentiate between satisfactory and unsatisfactory boiler operation. It should be apparent, however, that water containing a total of 2 grains per gallon of incrusting solids will permit of twice as great a concentration as water containing 4 grains per gallon. Another important factor in the purification of boiler feed, not always given due consideration, is the result of irregularity in softening as it affects the accumulation of precipitates within the boiler. If, for instance, the softening effect is one day carried out to 2 grains incrusting solids; the next day 4 grains, and the succeeding day 2 grains; at times an excess of reagents and at times an insufficiency of reagents, the cumulative effect of these irregularities is evidenced by an over-accumulation of precipitates within the boiler, and such a condition is frequently the cause of priming and foaming. To overcome such a condition, the general practice on the part of those responsible for the operation of the boilers is to reduce the treatment with soda ash so that, instead of an accumulation of precipitates, a deposition of scale occurs which usually stops the foaming; the verdict then being that too much soda ash was being used in the water. As a matter of fact, it is not the amount of soda ash being used in the water but the irregularity with which the treatment of the water was being made.

Recording and Regulating Appliances for the Steel Works Boiler Room.

Emphasis Given to the Fuel Economies Which Can Be Effected in the Steel Mill Power Plant by the Proper Use of Recording and Regulating Appliances.

By F. J. DENK.

TWENTY-FIVE to 50,000,000 tons of coal a year are wasted in industrial power plants in this country, according to statements made by the Bureau of Mines, Bulletin No. 4, which can be saved without changing the present equipment. Improved operation, careful supervision and good judgment are the requirements to accomplish this end. By improving operating conditions, fuel waste will be reduced, but it is not only necessary to improve conditions, they must be kept going by careful supervision, else the operators will fall back to their old methods of working and all previous efforts for betterment will become void. We, furthermore, must have means of knowing positively, that the improved operating conditions are actually kept going. For this purpose we need recording and regulating appliances, in the selection of which the boiler house superintendent has to show good judgment, so that he acquires those instruments which are best adapted for his purposes. He also needs good judgment when showing his men the benefits which can be derived from using such appliances. Many of these boiler room operators view the instruments with suspicion, believing that they are put there to "show them up" and many a time the writer, when talking about installing controlling and

efficiency devices in a boiler room was told: "I have been running boilers for 30 years and I know all about them. We do not need any instruments in this boiler room." As long as coal was \$0.80 a ton, delivered at the boiler plant, such conditions did not hurt very much, but times have changed and the boiler room superintendents know, that with the present high prices for fuel, savings must be effected in order to meet competition. A short example will show this to be true. Supposing we have a boiler room containing five 600 hp boilers using 5 pounds coal per hp hour. This would mean a consumption of 180 tons of coal per day. With coal at \$0.80 per ton the fuel cost was \$144.00 per day, while with coal at \$5.00 per ton, we have a fuel cost of \$900.00. A preventable waste of 20 per cent meant a loss of \$28.80 in the first case, whereas it represents a loss of \$180.00 in the second case. A fair idea where these preventable fuel losses have to be looked for can be had by comparing figures No. 1 and No. 2. The first shows a graphic representation of the heat losses in a boiler operated under conditions as they are usually experienced, while the second figure illustrates the losses in the same boiler, after the operation was improved.

The comparison shows that the largest loss is

Analysis of Heat Losses in Boiler, Showing How Efficiency Can Be Increased by Better Operation.



Fig. 1—Graphic representation of the heat losses in a 250 hp steel works boiler illustrating average working conditions.

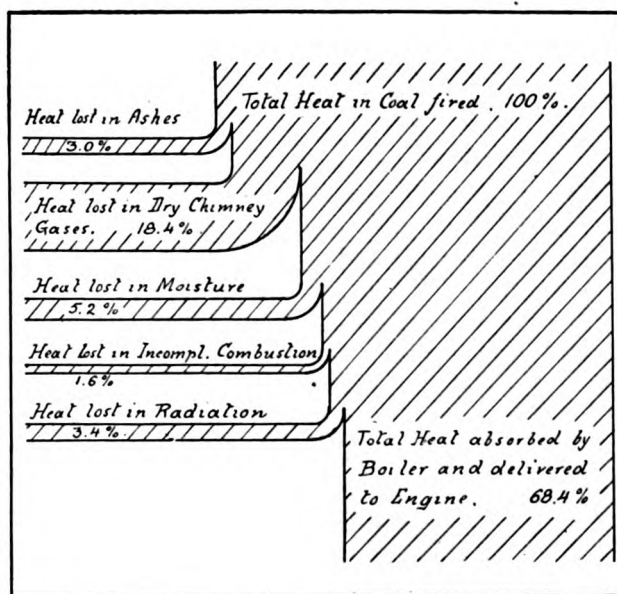


Fig. 2—Graphic representation of the heat losses in a 250 hp steel works boiler illustrating improved working conditions.

caused by the heat carried away with the hot waste gases. The chimney losses are due to three different causes:

1. To the excess air used in burning the fuel.
2. To incomplete combustion.
3. To the heat in the moisture.

The moisture in the waste gases comes partly from the free moisture in the coal, partly from the oxidation of the hydrogen in the coal and partly from the air. Of these losses, the one under item 3 depends on the kind of fuel and on the moisture in the air and cannot be controlled. This is practically a fixed loss which varies only with different kinds of fuel.

The losses, enumerated under item 2 can be eliminated entirely. They are due to the presence of CO in the flue gases which, in turn, show deficiency in air. A properly designed furnace with a combustion chamber of ample size, which allows proper regulation of the air admitted, will prevent such losses entirely.

The greatest percentage of the heat losses, due to the waste gases, is caused by excess air as mentioned under item 1. This is the point where fuel saving can be effected.

Approximately 12 pounds of air are necessary for the complete combustion of one pound of coal. This is the theoretical quantity required, but it is insufficient for actual operation. Due to the composition of the coal and air, and due to the conditions of the firebed, an excess of air over that amount is needed to insure proper working of the boiler furnace and to give satisfactory results. This excess amounts to about 100 per cent for hand-fired boilers with natural draft, while with stokers it should not be more than 40 per cent. In most cases, however, the percentage of excess air is much higher than shown here, and the reason for such a condition is mainly to be found in a more or less careless operation of the boilers. Excess air decreases the amount of CO₂ in the gas, and anything less than 12 to 14 per cent of this constituent in the flue gases shows a waste of fuel. Fourteen per

cent CO₂ corresponds to about 40 per cent air excess, and this figure should be obtained when making a flue gas analysis, provided we have modern boilers. These conditions are illustrated in figures 3 and 4. Fig. 3 gives the percentages of CO₂ for different quantities of excess air, and Fig. 4 shows the percentage of preventable fuel loss for different percentages of CO₂. As 40 per cent is the permissible minimum, the preventable fuel loss for 40 per cent excess air is called "zero." The curve is calculated by means of the formula:

$$\text{Preventable fuel loss} = \frac{\text{per cent air excess} - 40}{12}$$

and shows plainly the increasing loss with increasing

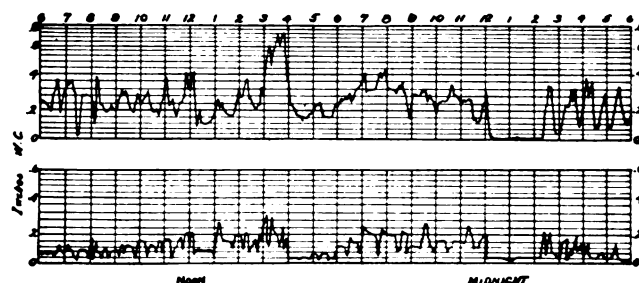


Fig. 5—Actual diagram from a differential draft-draft recorder.

percentage of excess air or with decreasing percentage of CO₂. It can, therefore, be seen, that a certain definite relation exists between the amount of CO₂ in the flue gases and the preventable fuel losses, and that the losses can be reduced to a minimum by improving the operation of the boilers.

Improving, for example, the conditions, as shown in Fig. 1 to those illustrated in Fig. 2 reduces the heat losses in the chimney gases from 30.0 per cent to 18.4 per cent. This was effected by reducing the quantity of excess air from 175 to 78 per cent or increasing the amount of CO₂ from 7.2 per cent to 11.2 per cent. This shows a reduction in the preventable fuel loss.

Curves Showing the Relation Between the Carbon Dioxide, Excess Air and Fuel Loss.

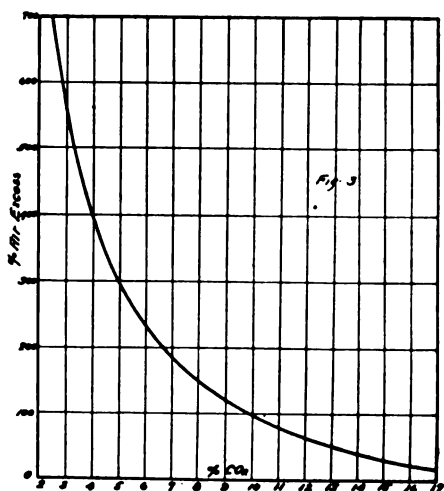


Fig. 3—Relation between per cent excess air and carbon dioxide contents in flue gas.

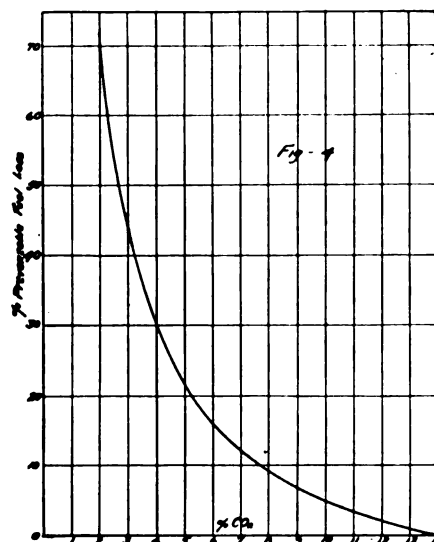


Fig. 4—Relation between per cent preventable fuel loss and carbon dioxide content in flue gas.

according to curve No. 4, of 8.5 per cent. The fuel, thus spent in heating up unnecessary air, can be used for increasing the power output.

An increase in CO_2 is always accompanied by an increase in the temperature of the waste gases and it is a belief, widely entertained, that the increase in temperature causes an increase in the heat losses due to the chimney gases. This, however, is not the case. Increase in CO_2 means decrease in the percentage of excess air, but this relation does not follow a straight line, but a curve, as shown in Fig. 3. We have, therefore, smaller absolute quantities for the higher temperatures than for the lower ones and, for this reason, the losses will be smaller.

From the preceeding it can be seen, that the question of operating the boilers efficiently and satisfactorily can be traced back to controlling and regulating the quantity of excess air. It would, of course, be asking too much of the men in charge of the boilers, to trace all irregularities, which may occur during a day, to this one point. For this purpose, and as an aid to the boiler operator, there have been developed, as was stated at the beginning of this article, a number of regulators and recorders, which are supposed to take care of these irregularities and to either remove them automatically or to assist the boiler operator in discovering them and then remove them by hand. These appliances can be grouped into two classes, viz.:

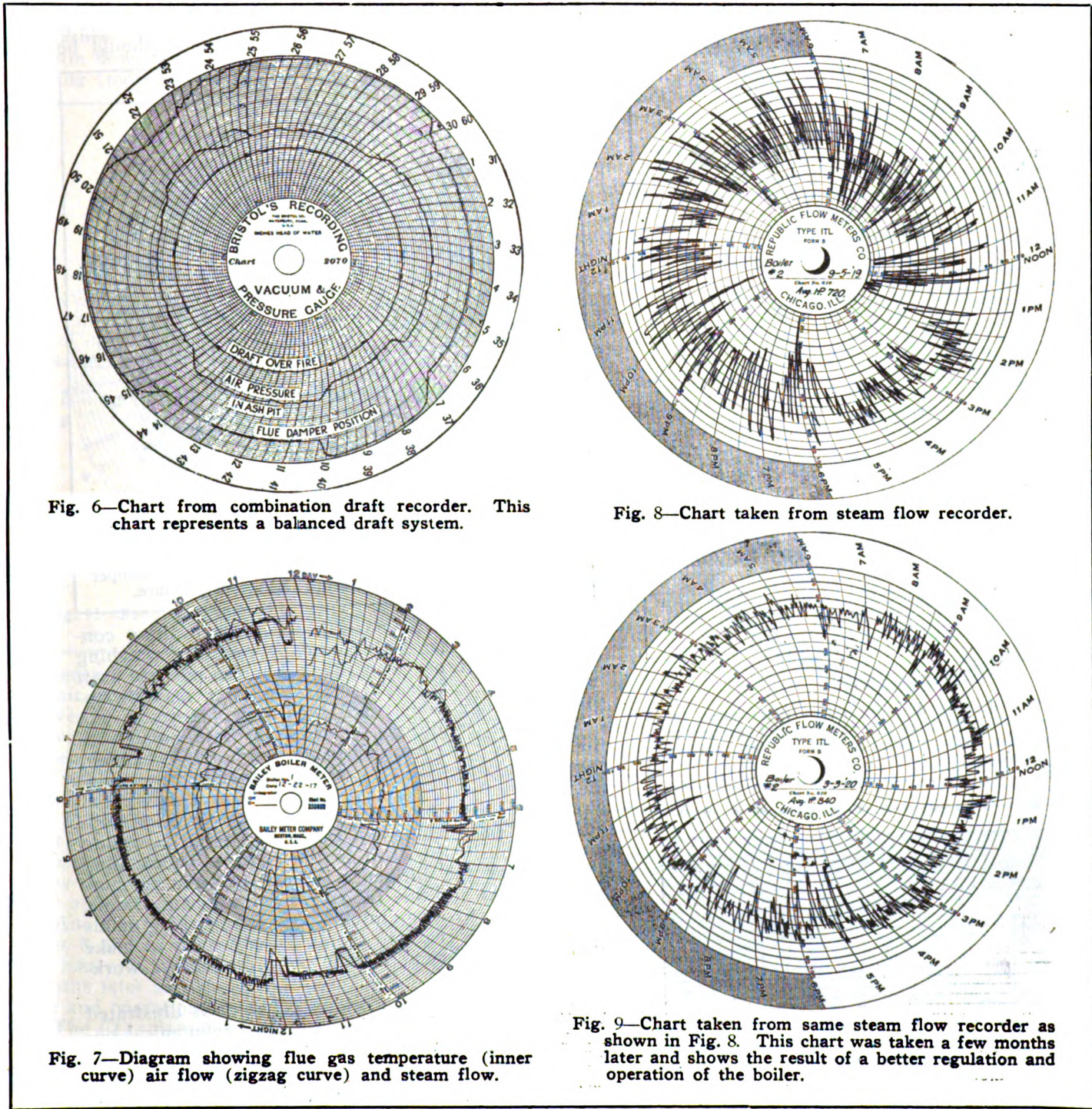


Fig. 6—Chart from combination draft recorder. This chart represents a balanced draft system.

Fig. 8—Chart taken from steam flow recorder.

Fig. 7—Diagram showing flue gas temperature (inner curve) air flow (zigzag curve) and steam flow.

Fig. 9—Chart taken from same steam flow recorder as shown in Fig. 8. This chart was taken a few months later and shows the result of a better regulation and operation of the boiler.

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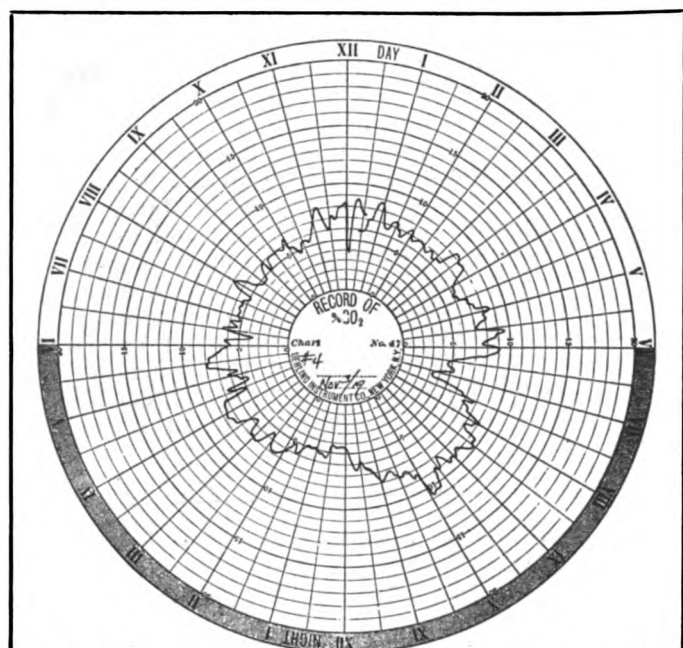


Fig. 10—Carbon dioxide diagram. This diagram represents the conditions after the installation of the carbon dioxide recorder but before the fireman was instructed in the use of the new instrument.

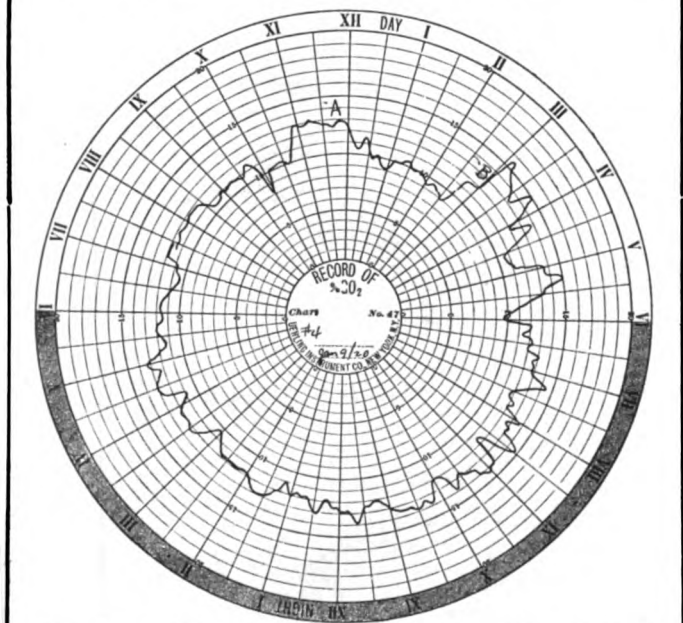


Fig. 11—Carbon dioxide diagram taken from same installation as Fig. 10 after the fireman had learned to profit by the information given by the carbon dioxide recorder.

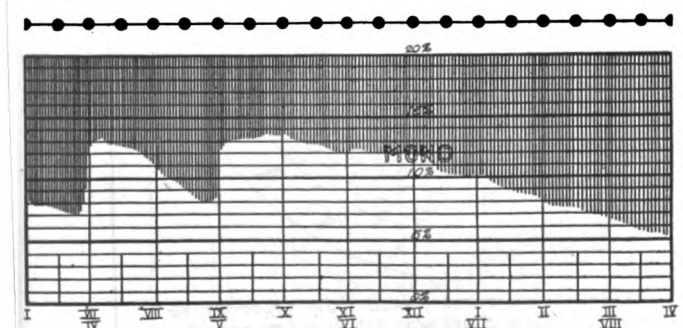


Fig. 12—Carbon dioxide chart taken simultaneously with the carbon monoxide chart in Fig. 13.

1. Boiler efficiency instruments, and
2. Boiler regulating appliances.

To the first group belong draft recorders, temperature recorders, steam flow meters, steam pressure recorders, CO_2 and CO recorders, while the second group comprises damper regulators and feed water regulators.

In the following we will show a number of charts, how these different instruments and appliances work and how they can be used for the purpose in question, i. e.: an efficient boiler operation.

Fig. 5 represents a chart from a differential draft-draft recorder. Draft recorders are used to record the draft at different places in the boiler. A certain amount of air is required for economical combustion and the quantity varies with the kind of coal fired and also with the position of the damper. This amount has to be determined by experiment, and after this is once accomplished, the quantity required should be

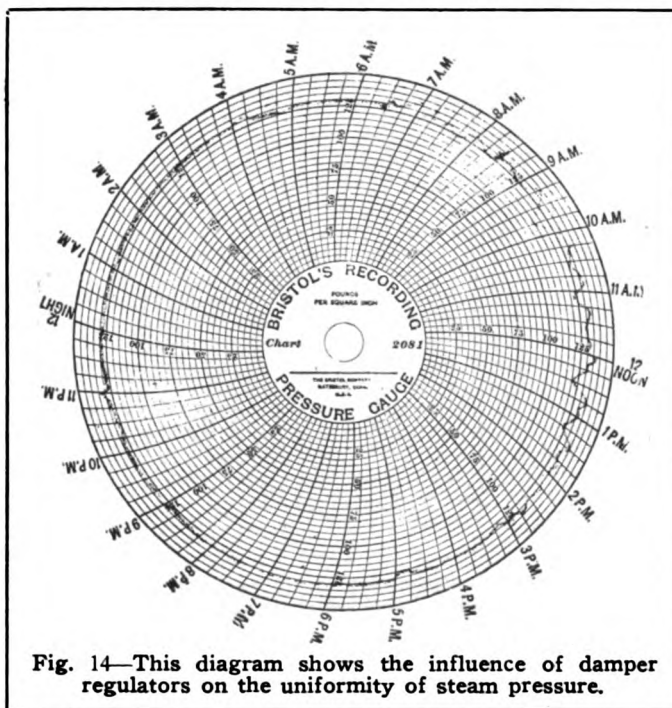


Fig. 14—This diagram shows the influence of damper regulators on the uniformity of steam pressure.

kept as constant as possible for the prevailing conditions, which can be effected by carefully watching the drafts in furnaces and flue. For this purpose draft recorders or differential draft recorders may be applied although when used separately, they do not give, for all conditions, a criterion, safe enough to judge from it the working in the combustion chamber. This is accomplished by either combining the readings of the two instruments, or by using a differential draft-draft recorder which instrument combines automatically the readings of the other two, recording simultaneously the draft in the combustion chamber (below) and the difference in draft between combustion chamber and flue (above). The fireman is, thus, in a position to judge intelligently the working of his furnace and to regulate the air supply so as to make this supply sufficient for the most economical working of his boilers.

For the boiler, the working of which is illustrated in Fig. 5, it was found that the most economical operation could be obtained when the draft in the combustion chamber was 2 inch wc with a differential draft of 38 inch wc. This is "normal operation."

Overload will be indicated when both drafts are higher, underload when both drafts are lower, than normal, while excess air is shown by an increase in differential draft combined with a decrease in draft in the combustion chamber. Lack of air is shown by the reverse condition. According to this explanation, it can easily be seen, that, during most of the 24 hours in question, the boiler was operated below its rated capacity.

Another type of a combination draft recorder is shown in Fig. 6, which represents a chart from a balanced draft system. While the position of the damper and the pressure in the ashpit vary, the draft over the fire in the furnace chamber is practically constant, thus showing that any predetermined pressure may be maintained in the furnace chamber for all rates of combustion.

Fig. 7 illustrates a diagram showing flue gas temperature (inner curve), air flow (zig-zag curve) and steam flow, the latter expressed in per cent of boiler rating (more or less smooth curve close to air curve).

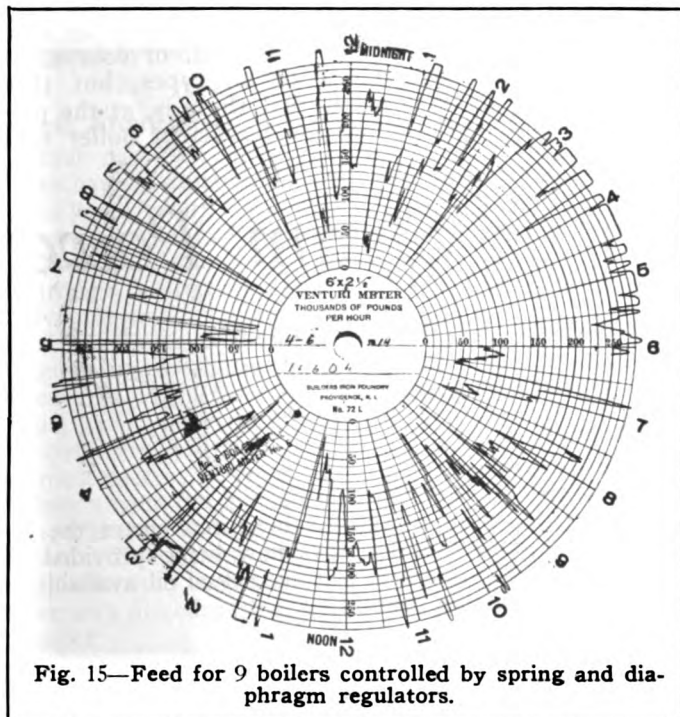


Fig. 15—Feed for 9 boilers controlled by spring and diaphragm regulators.

Whenever the air and steam curve coincide, there is no air excess. If the air curve lies above the steam curve, we have air excess, if it comes below the steam curve, air deficiency. Thus it can be seen, that between 12 noon and 1.30 p. m., there is an excess of air, while from 10:30 to 11:30 the next morning there is some deficiency of air. During the remainder of the 24 hours, the conditions are kept reasonably good, except at times of dumping at 6:00, 10:15 and 11:15 p. m., and at 6:30 and 10:30 a. m. The charts also show the close relation between the flue gas temperature and the rate of steam output.

Another type of steam flow recorder is shown in Figs. 8 and 9. Chart No. 8 was taken shortly after the meter was installed, while No. 9 was taken a few months later and shows the result of a better regulation and operation of the boiler.

The CO_2 diagrams are reproduced in Figs. 10 and 11. They belong to the same boiler, equipped with a stoker furnace, and they show the influence of teaching the boiler operators. Diagram No. 10 illustrates

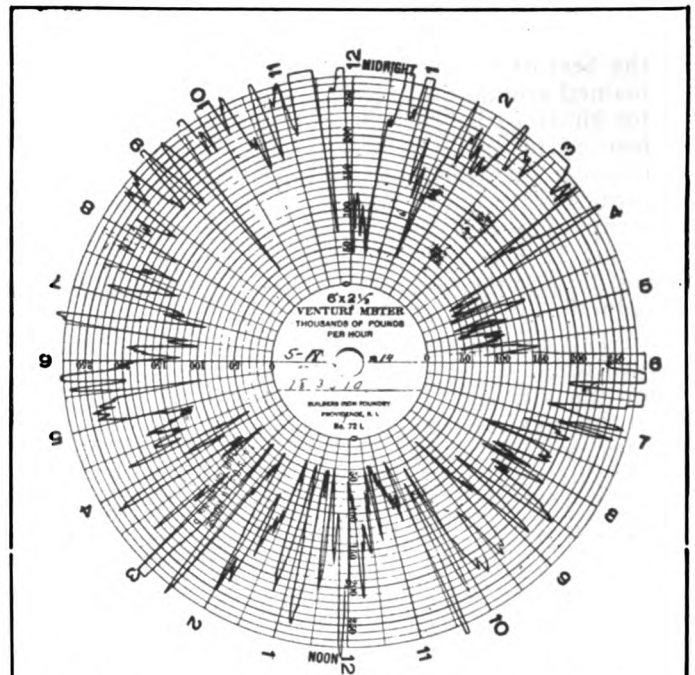


Fig. 16—Same conditions as Fig. 15, with 8 boilers instead of 9.

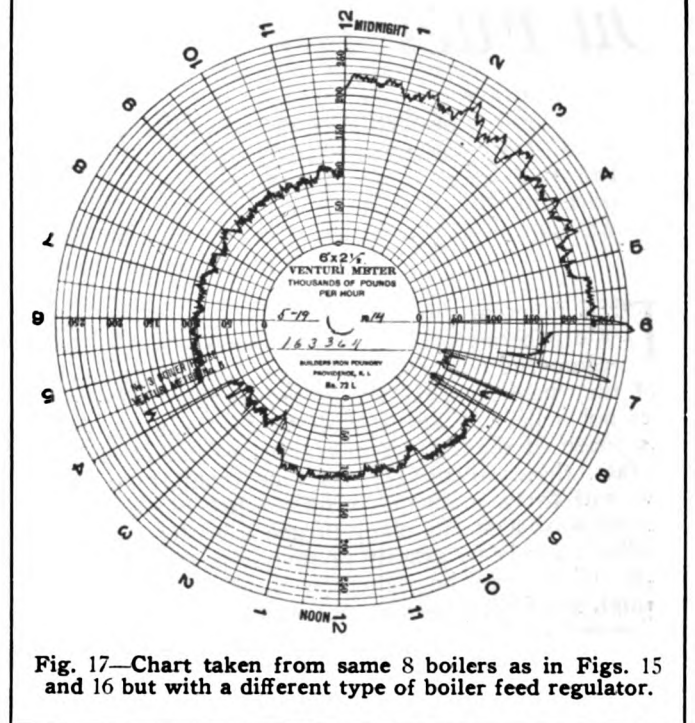


Fig. 17—Chart taken from same 8 boilers as in Figs. 15 and 16 but with a different type of boiler feed regulator.

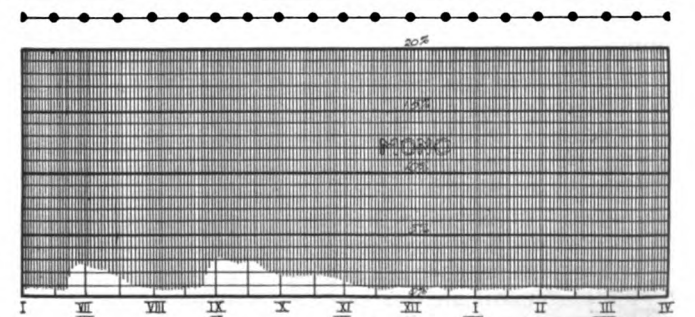


Fig. 13—Carbon monoxide chart taken simultaneously with the carbon dioxide chart shown in Fig. 12.

conditions after the installations of a CO₂ recorder, but before the fireman was instructed in the use of the new instrument. He was running the stoker to the best of his ability and the percentages of CO₂ remained around 6 per cent most of the time, increasing for short periods to about 9 per cent. After he had learned to profit by the information which the CO₂ recorder furnished, he obtained the chart, Fig. 11, and continued to obtain charts showing marked improvement. The percentage of CO₂ on this chart averaged about 12 per cent; it seldom fell below 10 per cent and frequently exceeded 13 per cent. Thus a marked reduction in the stack losses was effected.

The percentage of CO₂ varies with the kind of fuel used, the method of firing, the method of admitting air, etc. In one installation 14 per cent may be the maximum that should be obtained, in another, 8 per cent; in a third, 24 per cent (blast furnace gas). For this reason it is well to record the CO simultaneously with the CO₂. A set of charts of this type is given in Figs. 12 and 13, Fig. 12 illustrating the CO₂ curve and Fig. 13, the CO curve. When taken in such a way, the curves give an absolutely accurate account of the furnace conditions.

The influence of installing damper regulators on the uniformity of the steam pressure can be seen from Fig. 14. The time between 6:30 a. m. and 3 p. m. represents the average operating conditions. At 3

p. m. the regulator was put into commission and the curve from that time until 6:30 a. m. of the following day shows the effect on the steam pressure of controlling the fuel and air supply in accordance with the steam demand.

A set of three charts, showing the superiority of a certain type of feed water regulators, is illustrated in Figs. 15, 16, and 17. Fig. 15 shows feed to 9 boilers controlled by spring and diaphragm regulators. Fig. 16 shows the same condition, but with 8 boilers instead of 9, and Fig. 17 shows a chart from the same 8 boilers, but installed with the new type of regulators instead of the old ones. The period between 6 a. m. and 8:30 a. m. on the last chart illustrates the cutting into service and the adjusting of the new regulators. The chart, after midnight, shows 17 boilers in operation.

In the preceeding it was intended to show on a few representative samples the working of modern boiler room equipment and how such instruments and appliances can and should be used to improve the working of the boilers and eliminate waste as much as possible. The limited space, did, of course, not allow to reproduce charts of all types, but those shown will suffice to prove that there is, at the present time, no more excuse for inefficient boiler room operation.

Oil Fuel for Generation of Steam Power

Advantages of Oil Fuel—Cost and Labor Saving—Types of Burners—Mechanical and Steam Atomizers—Importance of Proper Furnace Design for Oil Fuel.

By ERNEST H. PEABODY,
President, Peabody Engineering Corporation.

THE inherent advantages in the use of oil fuel for the generation of steam for power, particularly as compared with coal, have been enumerated so often that they have become almost stereotyped. The writer does not believe it worth while to devote much space to this phase of the subject in a short article of this kind. In fact, these advantages must be manifest to anyone who will for a moment consider what it means in the operation of a steam plant to use a fuel which can be handled entirely by gravity or pumps instead of by hand labor, which can be delivered to the boiler furnaces through small pipe lines at moderate pressure, which can be burned without smoke or ashes, which, with proper equipment gives the highest possible boiler efficiency, and which is capable of maintaining this efficiency through a wide range in load by the mere adjustment of a valve and regulation of a damper.

Supply.

Oil is indeed the most desirable and ideal fuel, and there are only two questions which the prospective user will need to ask before deciding to equip his plant for burning oil. The first question is, can the oil be secured with proper regularity and in proper amount to fill the requirements of the plant? Second, what is the relative cost as compared to coal or other available fuel?

These questions are both local in character; that is, no definite general answer can be given to either.

The first question will depend largely on location, but

it is probable that within the next few years the increased transportation facilities now being provided by the oil producing interests will make fuel oil available in many sections of the country.

Cost.

The second question, that of relative cost must include not only comparative prices and heat values of oil and other fuels, but also the saving due to reduction of labor costs (and elimination to a large degree of labor troubles), lower maintenance charges, greater efficiency of the boilers, a possible reduction of the number of units in service, and what proportion these various economies may bear to the interest charges on cost of installation.

McFarland's Rule.

As a rough basis for estimating whether or not the relative prices of oil and coal will permit of the use of the former, McFarland's rule provides a general starting point. Assuming average heat values for the two fuels, and the possible increased efficiency of oil burning boilers, McFarland noticed that when the cost of the coal in dollars per ton (2,240 lbs.) was double the cost of the oil in cents per gallon, the fuel cost of producing a given amount of boiler hp was approximately the same. Thus, coal at \$8 per ton would about equal oil at 4c per gallon. This rule, like all empirical statements, while useful, is only approximate and is greatly affected by the

relative heat values of the two fuels and should only be used for a rough estimate; further, it is to be borne in mind that this estimate makes no allowance whatever for labor saving which, in plants of large and moderate size, is always in favor of the oil.

Labor Saving.

It is not unusual in large stationary plants to find one fireman handling as many as 30 burners (and sometimes more), developing say 8,000 to 10,000 boiler hp. It would take about 16 firemen and four coal passers to develop the same power with coal hand-fired. Therefore, it is evident that the saving in labor by the use of oil may be very great and it is misleading to base any decision relative to the possible use of oil on the price of oil alone.

Types of Burners.

It is universally recognized that the most effective way of handling oil fuel in boiler furnaces is to inject the liquid into the furnaces in the form of a spray. "Burners," so called, are therefore in reality atomizers. These may be divided into two great classes: First, those which employ an atomizing medium such as compressed air or steam for producing the spray, and those in which the oil is atomized by means of centrifugal force induced by pressure.

Mechanical Atomizers.

In recent years the latter type, which are frequently called "mechanical atomizers" have been largely used for marine purposes where the simplicity resulting from the use of small single pipe lines carrying the oil to the burners, coupled also with the fact that no fresh water is lost through the burners, has made this type particularly advantageous. Mechanical atomizers have not been used to a great extent in stationary plants on shore as yet, but it is now being recognized that they possess salient features which make their employment in stationary plants, particularly those where high peak loads are encountered, very desirable.

The most successful types of mechanical atomizers in use produce a round or conical spray, the air for combustion being admitted through special air regulators around the burner. The design of the regulator is most important, particularly in water tube boilers where a number of burners discharge the air into a common combustion chamber.

Steam Atomizers.

Compressed air and steam atomizers may produce either a round, conical flame or a flat fan-tail shape, according to the design of the burner, the latter being particularly applicable to the stationary type of water tube boiler as distinguished from the Scotch boiler, so often used for marine purposes, in which the furnaces are cylindrical in shape.

Compressed air is now very seldom used for atomizing for steam power work, as the use of dry steam is quite as effective and eliminates at once the necessity for a compressor and a much more elaborate system of piping with their attendant disadvantages of first cost and maintenance charges. On the other hand, compressed air atomizers, that is, the types using air at low pressure supplied by blowers, are very commonly used in industrial furnaces and are invariably to be preferred when furnaces of this type are situated at a remote point from the boilers. It is a fallacy to suppose however, that compressed air produces any better spray than steam, or that because the oxygen of the air supports combustion, it possesses any superiority for atomizing oil in a boiler furnace. Authentic tests with steam atomizers have

shown them to give gross boiler economies exceeding 83 per cent efficiency, which is about the maximum which can be expected.

Relative Advantages.

A boiler user will therefore need to consider only two types of burners. The round mechanical atomizer and the flat flame steam atomizer, and whether one or the other will be preferred is a matter of purely local conditions. This is on the assumption, of course, that fresh water may be had in ample quantity, so that the waste of fresh water due to the steam used for atomizing amounting to $1\frac{1}{2}$ or 2 per cent of the output of the boiler will not result in any disadvantage.

In general, it may be said that the mechanical atomizer is to be preferred for two reasons. First, the system is susceptible of developing much higher boiler ratings, and it removes from the hands of the operating personnel all use of steam for atomizing and the possibility of excessive wastage from this cause through carelessness. The use of the mechanical atomizer, however, usually involves the removal of the grate bars and the installation is somewhat higher in first cost. Thus the steam atomizer can be installed through the front furnace doors, leaving the grate bars intact and by merely installing a layer of firebrick over the bars in a suitable way the air for combustion may be admitted through openings and underneath the burner spray.

If, therefore, a boiler capacity of say 100 per cent above rating is sufficient, the steam atomizer will prove entirely satisfactory in the hands of a careful fireman. The steam atomizer requires also somewhat less draft pressure for given rates of operation, and therefore lower chimneys can be utilized. But if the boiler will require forcing to over 200 per cent above rating the mechanical atomizer and the use of forced draft becomes necessary, and allowing for the inherent carelessness of the ordinary fireman, the economic results are likely to be superior.

What Not to Do.

The large number of patents which have been taken out on oil burners, particularly those of the steam atomizing type, indicate that it is not a difficult matter to produce something which will spray oil. In fact, an ordinary piece of iron pipe flattened down on the end can be made to serve. It is not uncommon to find in some boiler plants burners of "homemade" construction, usually the invention of the chief engineer; and the appearance of the fire, which to the uninitiated is deceptive, is likely to persuade the owner that his chief engineer has saved him a lot of money that he might otherwise have squandered in the purchase of "patent" oil burners. This is a very fallacious reasoning and is a good illustration of the old saying: "Save at the spigot and lose at the bung." There might have been causes in the past where oil could be had at so low a price that a homemade burner costing a couple of dollars might not waste enough oil to offset the first cost of an economical atomizer. If such cases have existed in the past, they surely exist no longer, for, with the advancing price of oil, it becomes more and more important to select equipment which will give the very best economic results.

Thus, while it is "easy" to burn oil, and while it is true that oil fuel is susceptible of giving results unsurpassed in economy, it is also true that the amount of waste of good fuel which is possible in an oil burn-

ing plant is almost limitless. The writer has frequently had occasion to point out that a coal fire even in the hands of the most careless fireman has certain distinctive limits of inferiority below which it cannot go. In other words, a coal fire, when it gets too bad, will quit the job and go out. An oil fire will keep on burning, and to all outward appearances, make a very creditable showing, even though 20 per cent. of the steam output of the boiler is wasted through the burners, and the excess air were 10 times what it ought to be.

In these days of "conservation" therefore, the skilled designer of oil burning equipment finds a decided justification for his efforts and his experience will be worth something to the prospective user.

Furnace Design.

It may be well to point out here that the best development in the art of oil burning includes a great deal more than the mere storage, handling and spraying of the oil. The furnace design is of the utmost importance, and, coupled with the proper admission and control of the air for combustion, represents perhaps 90 per cent of the problem. Target walls against which the oil flame was made to impinge in early designs are now no longer used, and it is no longer found necessary to construct tortuous passages through the furnace brickwork for heating the air. A better understanding of combustion requirements have tended in modern equipment to greater simplicity, and it is not necessary to resort to complicated designs to secure complete combustion without

smoke and with entire immunity from damage due to local overheating of the boilers.

Simplicity in design may indeed be placed among the first of the requirements of the modern oil burning outfit, and this bears particularly on the design of the furnace and burners where the question of repair and cleaning is of paramount importance.

Viscous Oil.

It is probable that the future trend of the oil industry will result in placing on the market for fuel purposes a more viscous oil than has been used in the past. Viscosity may be reduced by heating and some of these oils require heating even to be handled in the pumps. The ultimate results in the furnaces with viscous oils are not greatly different from those obtained with light fluid oils, providing always that the equipment is designed for the purpose. The storage, pumping and atomizing of heavy viscous oils, however, requires very different provisions from those which are entirely satisfactory for the lighter variety of oils and which are usually very fluid. Equipment which will handle light oils with entirely satisfactory results may prove absolutely worthless with viscous oils.

The writer wishes to point out this fact most emphatically, for he believes that the owner of a steam plant today who installs equipment which will not take care of oil from 10 to 12 Baume, which are usually very viscous, is taking a chance which the promise of the future does not justify.

Advantages of Superheat Steam Operation

Results of Superheating Are Evidenced by a Considerable Reduction in the Cost of Operating a Steam Plant—Within Practical Limits Economy Increases With Superheat.

By D. D. PENDLETON,

Sales Engineer, Locomotive Superheater Company.

THE value of fuel used annually in this country alone is estimated at over \$2,000,000,000.

Because fuel used for power plant or power station service represents the largest single item in the cost of producing power, its utility must be increased. Each pound of coal burned, each gallon of oil consumed under a boiler for the generation of steam not only must be accounted for, but also must be made to do more useful work.

Of all the means known or practiced to improve the efficiency of a plant, the application of high degrees of superheat, for the investment, shows the most profitable and practical returns. Because superheat offers economies greater than any other single improvement in power plant design, it commends itself to even closer consideration than engineers have hitherto given it.

The returns from superheating are evidenced by a considerable reduction in the cost of operating a steam plant. Within practical limits of temperature, it has been found that the higher the superheat, the greater the economy.

The increased economy is effected in general in four ways, viz.: By increasing boiler efficiency, by reducing condensation losses in steam lines, by re-

ducing the steam consumption of the prime mover, and by increasing the capacity of the plant.

Superheating Increases the Boiler Efficiency.

A definite amount of heat is required to superheat steam to a certain temperature and this heat is furnished by the fuel. When a definite weight of steam is generated, additional fuel will be consumed to superheat this steam.

Let us assume a boiler designed without a superheater to give the highest practical thermal efficiency. Suppose we install a properly designed superheater in this boiler. It will be found that the overall thermal efficiency of the combined boiler and superheater will be greater than the boiler without the superheater when evaporating the same amount of water, because by the addition of the superheating surface more heat is absorbed and the final uptake gas temperature is lowered. This result can be accomplished, however, only when the superheater is correctly designed so as not to obstruct unduly the flow of the gases through the boiler. Undue obstruction to the gases would decrease the overload capacity of the boiler. A properly designed superheater will not alter furnace conditions in any way. Considering a

given furnace condition and a given rate of firing, these facts are indications of added efficiency.

Eliminating Steam Line Condensation.

Many power plant installations are forced by local conditions to operate their prime movers at long distances from the boilers supplying the steam. The long pipe lines carrying the steam often are run out of doors where they are exposed to all kinds of weather. These conditions naturally have a marked effect on the quality of steam when it reaches the point where it is to be used.

Superheated steam prevents condensation in steam lines and delivers dry or superheated steam within practical limits to the steam user. This advantage is due to the fact that no moisture of water is carried over from the superheater and also because the low thermal conductivity of the superheated steam prevents condensation. Superheating is advantageous not only from an economical standpoint, but also because it eliminates water hammer and its attendant engine and pipe troubles.

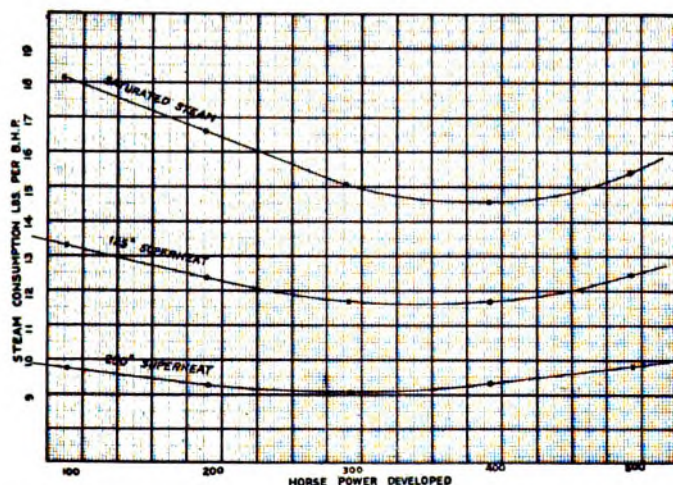


Fig. 1—Steam consumption of a 250 hp compound condensing engine at different loads.

It is a matter of historical interest that the first recorded use of superheated steam was necessitated by the condensation which took place in a long steam line.

Long pipe lines now carrying saturated steam can be used for superheated steam without any change, resulting in a great saving in the available heat and quantity of steam delivered for power purposes. This fact alone should make the use of superheated steam on long pipe lines universal practice.

When condensation in steam lines is reduced, both steam and coal are saved, because in the generation of steam, about nine-tenths of the heat absorbed by the water in evaporating it and raising the steam pressure is latent heat. When steam is condensed, latent heat is liberated and unless it performs useful work it is wasted. Condensation, therefore, occurring in pipe lines, represents an absolute waste of nine-tenths of the heat, and if the condensate is not returned to the boiler all the heat is wasted. A superheater is absolutely essential to raise the temperature of the steam to a point that all of it may be transmitted to its destination and used without condensation losses.

Importance of Superheat in Steam Turbines.

High degree superheat is of vital importance in

steam turbines, and the steam turbine is particularly adapted to its use. All turbine plants of any size are now using superheat, several modern plants operating at superheat temperature up to 250 degrees. Turbine manufacturers have made a strong claim in favor of turbines, in that high degrees of superheat can be used. The most economical steam prime movers of today utilize steam as high as 300 degrees superheat. These turbines produce a kwh for 11.5 pounds of steam or a brake horse power hour for 8 pounds of steam.

The water rate of an economical steam turbine will be reduced 1 per cent for every 12 degrees of superheat up to 200 degrees. This figure is based on large and economical turbines. Small turbines inherently less economical, show a greater proportionate saving with superheated steam.

The above results are based upon the assumption that perfectly dry steam has been delivered to the superheater. This condition, however, seldom exists. The usual type of horizontal return tubular boiler with a comparatively large water and steam capacity

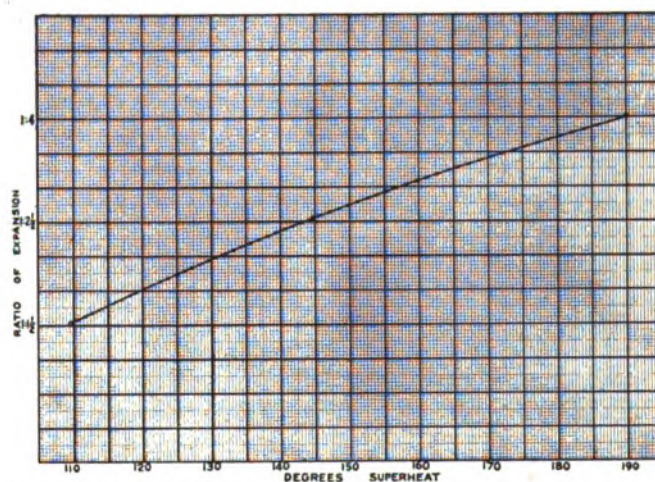


Fig. 2—Superheat required to prevent condensation for various ratios of expansion in reciprocating engines.

delivers wet steam. The modern water tube boiler with less water and steam space is much worse. This condition is accentuated, particularly by the fact that the modern water tube boiler is forced to evaporate water at a rate 3 or 4 times that of the return tubular boiler, and the percentage of moisture in the steam from such a boiler is high. Take for example a 500 hp water tube boiler having a 42 inch diameter steam drum. At normal rating such a boiler will deliver 15,000 pounds of steam per hour. Conditions often arise when such a boiler will be called upon to evaporate 30,000 to 40,000 pounds of water per hour. Superheat takes out all the moisture that otherwise would be carried over and is, therefore, particularly beneficial when boilers operate at high capacities.

It is this moisture which is particularly damaging to steam turbines. It reduces the efficiency by the excessive friction between the water and turbine parts. One authority points out that a turbine without superheat is merely a form of water brake, for every ounce of water passing through, no matter how finely divided, is inert material, and serves only to check the running of the machine.

The internal surfaces of the turbines are enormously increased beyond those in reciprocating engines, and the effect of temperature range in augmenting

condensation is very great, even though the temperature in the turbine does not change so widely.

The destructive effect of water and moisture on the turbine blading is too well known to be more than mentioned. The erosion of turbine blades due to water is very rapid. The effect of this erosion is immediately felt in increased steam consumption. When highly superheated steam is used, however, wear is not present to cause this erosion. Blade wear is greatly reduced through superheating and re-blading is necessary only after much longer periods of operation than when saturated steam is used.

Superheating Increases the Efficiency of Reciprocating Engines.

Generally speaking, the reciprocating engine will be benefitted more by superheat than the steam turbine will. The saving to be expected by superheating is dependent on the amount of cylinder condensation that would occur in the same engine if no superheat were used. Evidently, the greater this condensation, the larger is the saving possible.

When steam is superheated 200 degrees or even 250 degrees F., it can be exposed to the cooling action of the steam chest and cylinder walls without condensation, and has 30 to 40 per cent greater specific

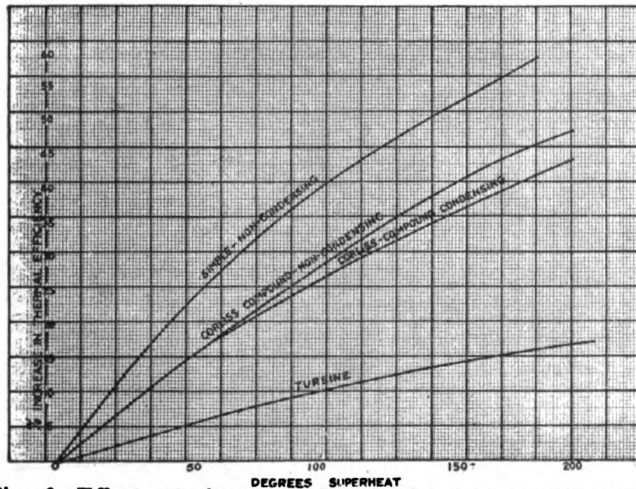


Fig. 3—Effect on thermal efficiency by various degrees of superheat.

volume than saturated steam of the same pressure. For example, 1 pound of water at 170 pound pressure absolute produces 2.68 cubic feet of saturated steam at 368 degrees F., temperature. After passing through the superheater and gaining 200 degrees superheat, the volume will have been increased to 3.54 cubic feet. A part of this increased specific volume is lost before the expansion of the steam in the cylinder takes place on account of the cooling action of the cylinder head, piston and cylinder walls. While the superheat in the steam entering the cylinder may be 200 degrees to 250 degrees, the superheat of the steam in the cylinder at the moment of cut-off is considerably less. The elimination of all condensation losses together with the increased volume of the steam, effects substantial savings in the steam consumption and in the fuel consumption when compared with saturated steam operation under the same conditions.

The opinion frequently has been advanced that the mean effective pressure in cylinders using superheated steam is altered from that existing when saturated steam is used, the initial pressure, the point

of cut-off and piston speed, of course, being assumed as the same in each case. Theoretical considerations would indicate that a lower mean effective pressure with superheated steam is obtained, and this conclusion would be based upon the knowledge that the expansion curve of superheated steam is steeper, that is to say falls more rapidly than with saturated steam. In practice, however, with highly superheated steam a mean effective pressure at least equal to that with saturated steam is obtained. An explanation will make this point clear. For example: In simple non-condensing engines the back pressure line of an indicator card is decidedly lower with superheated steam than with saturated steam, a condition to be expected because the steam exhausted contains less moisture. It is, therefore, lighter than saturated steam, and flows through the exhaust passages with less resistance. C. D. Young, before the American Society of Mechanical Engineers, in December, 1912, gave conclusive evidence of this fact.

In the case of multi-expansion reciprocating engines the cards taken from the low pressure, and, in the case of triple engines, from the intermediate pressure cylinder, show a higher m. e. p. is obtained with superheated steam. In the high pressure cylinder of multi-expansion engines it is generally true that the cut-off should be increased if the power output of the engine is to be maintained.

But our consideration of the possibility of increased engine power, due to superheating, must not stop here. Consider a saturated steam plant in which the boilers are operating at their full capacity to supply the steam demanded by the prime movers. Take this same plant and superheat it—the decrease in steam consumption per horsepower hour will result in a reserve boiler capacity which will make possible either the operation of the boilers at lower rating or will furnish the additional steam necessary to meet an overload on the prime mover. In other words, superheating makes it possible to increase the power which the prime mover may develop over what it could produce with saturated steam.

In new installations, the use of superheated steam permits the use of engines having larger cylinder diameters and enables them to be operated with shorter cut-offs. Because cylinder condensation is eliminated, the gain in economy due to a more effective expansion of the steam is realized.

Experiments have shown that the degree of superheat necessary to prevent cylinder condensation varies as a general rule with the ratio of expansion. In American practice the steam temperatures ordinarily recommended are: up to 500 degrees F., for Corliss and slide valves; up to 650 degrees F., to 700 degrees F., for piston and poppet valves.

The gain from decreased steam consumption due to superheated steam is ordinarily expressed in per cent. This gain will vary in various types of engines with the different superheat temperatures used. For example, with 150 degrees superheat, the following gains are produced: In simple engines, 22-24 per cent; compound engines, 16-19 per cent; triple expansion engines, 14-16 per cent; uniflow engines, 10-12 per cent. It is, however, an assured fact, and a strong argument for the more general adoption of high degree superheat, that only engines designed for high degrees of superheat and using it can successfully compete in economy in the power generation field.

Advantages When Operating at Reduced Pressures.

It is often necessary, particularly with old boilers, to reduce the operating pressure. This condition results in a loss in plant capacity. Superheating such boilers will enable them to meet the power demands of the plant at the reduced pressure just as well as the boilers did before the pressure was reduced. Furthermore, superheating in the majority of cases will provide an additional reserve power over that of the plant before the pressure was reduced.

Power Plant Cost With Superheat.

The installation of superheaters materially lowers the plant cost. Where it is used, a smaller amount of boiler horsepower is needed to deliver the same power. Roughly speaking, six boilers equipped with superheaters, furnishing 150 degrees of superheat, will carry the same power load as seven boilers delivering saturated steam. By reason of this fact alone, smaller feed pumps, smaller stacks, smaller coal handling apparatus and less coal storage space are sufficient for the demands.

Piping can be reduced in size, because higher steam velocities with superheated steam are possible. This reduction in pipe size will effect a saving not only in the pipe line but also in valves, fittings and covering.

In the turbine room, superheated steam will allow the use of a condenser of smaller size than if saturat-

ed steam were used. Consequently, smaller circulating water pumps, hot well and vacuum pumps can be used and minor apparatus such as steam separators often can be dispensed with.

Conclusion.

When superheating is correctly applied to the individual conditions in a specific plant, it is the one means which will positively show an improvement in power plant operation in at least one and probably all parts of the plant where steam is used.

All the more astonishing, therefore, becomes the fact that in spite of all these practical advantages, only about 15 per cent of the steam horsepower of this country is developed from superheated steam. Furthermore, this percentage represents not more than perhaps 5 per cent of all the steam power plants, indicating that only plants of large capacity, inherently more economical than the vast majority of stationary plants, use superheat.

Is it logical that comparatively few plants having high evaporation rates and low steam consumption, should be the ones to benefit by superheat, while 85 per cent of the nation's steam power uses fuel extravagantly? This condition is not consistent. The opportunity and the means to conserve fuel are available and the necessity is urgent.

(Abstract from paper read by the author before the Engineers Society of Western Pennsylvania.)

Economizers in Steel Mill Power Plants

**Existing Conditions in Steel Mill Power Plants Warrant Attention
As to the Advisability of Installing Economizers—Curves
Showing Percentage of Heat Combustion in Flue Gases.**

By J. LEE LAREW.

IN THE design of a power plant in connection with a steel mill, the question of an economizer installation has received very little attention, due perhaps to the fact that the designing engineers were of the opinion that the conditions which existed would not warrant its installation or perhaps the value of an economizer was not fully realized. This may have been the case in the design of some of our steel mill power plants in the past, but as a matter of fact, there are, at present, conditions existing in the majority of the steel plants which will bear acute observation and careful study. To appreciably understand the conditions under which it will pay to install an economizer, it is fitting that we observe some of the economizer installations, which are now in use in various steel plants throughout the country, especially those in and around the Pittsburgh district. By so doing, we will be able to form at least a fairly good opinion of the vast possibilities, which exist in the steel mill power plants to effect considerable savings by economizer installations.

First of all, consider the economizer itself. It is usually made up of a number of sections placed side by side, each section consisting, when assembled, of a top and bottom header, connected to each other by a number of tubes. These sections are connected together at the top and bottom by branch pipes, through which the feed water on the way to the boiler, enters

and leaves the economizer. The economizer is then placed in the path of the flue gases leaving the boiler on their way to the stack. This is done to permit the feed water to absorb a certain amount of the heat in the flue gases, which would otherwise be lost.

Fig. 1 represents a set of curves showing the percentage of combustion which passes off in the flue gases at various temperatures, each of the three curves, A, B and C, representing different conditions, as follows:

Curve A is based upon using 18 pounds of gas per pound of combustible in the fuel and represents the average underfeed stoker operation with forced draft.

Curve B is based upon using 24 pounds of gas per pound of combustible in the fuel, and represents average overfeed or natural draft stoker operation.

Curve C is based upon using 30 pounds of gas per pound of combustible in the fuel and represents average operation with hand firing or natural draft.

It is a well known fact that a high percentage of the heat in the fuel always leaves the boiler in the flue-gases, due to the fact that it is impractical as well as uneconomical to construct any boiler whose surface is large enough to transmit all of the heat generated in the furnace. Hence, when the condition is such that hot gases of a fairly high temperature pass off into the air, a certain amount of heat, which would otherwise be wasted, could be utilized by the

introduction of an economizer. If this is done, a greater evaporation in the boiler per pound of fuel burned will be the result, as well as a corresponding fuel saving.

The temperature relations existing in a boiler and economizer under average conditions should be carefully noted. Since the products of combustion are initially of a high temperature the transmission of heat through those parts of the boiler surface with which the gases first come in contact is very rapid, and the drop in the temperature of the gases is correspondingly precipitous. As the temperature difference becomes less, the rate of heat absorption falls off until a point is reached where the boiler surface no longer absorbs sufficient heat to pay the annual maintenance charges upon that particular surface. A

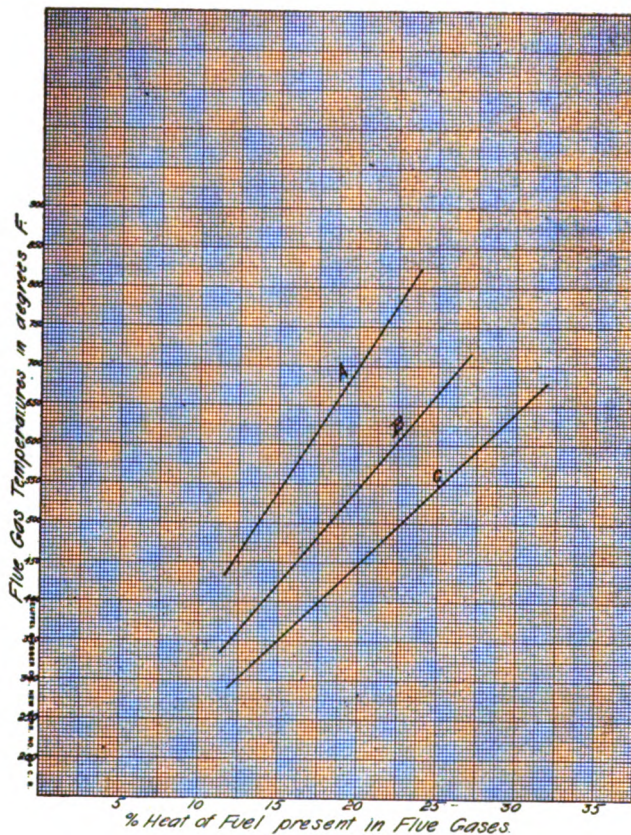


Fig. 1.

50 per cent addition to the boiler heating surface would lower the temperature approximately 100 degrees or so. However, by adding surface in the form of an economizer and introducing therein the cold feed water, the available "heat head" inducing the flow of heat can be multiplied by two or more, with a corresponding increase in profitableness, especially considering the fact that the annual charges on the economizer are less than on the boiler, square foot for square foot.

By the use of an economizer, feed water supplied to the boiler may be raised to a temperature above that of a hot-well, a feed water heater, or the ordinary water supply. The temperature to which the water has been raised after passing through an economizer will, under most conditions, closely approximate the temperature of the water in the boiler to which it is being fed. Accordingly, the higher the temperature of the feed water, the greater the proportion in fuel saving, or in other words an increase of capacity will

be obtained. This increase of capacity will range from 10 per cent to 15 per cent or even more, depending, of course, upon the power plant conditions.

In most, if not in all, the steel plants throughout the country and especially those in and around the Pittsburgh district, we find that the water which is available for boiler feed water use, is in very bad condition. This, naturally, is due to the fact that the water receives all sorts of contamination before it reaches the point where it is taken into the power plant. If this water is passed through an economizer in this bad condition, the heating of the water, while it is in the economizer, will be highly instrumental in its purification. True, to be sure, a certain amount of deposit will be formed in the bottom of the economizer sections. The preliminary heating of the water in an economizer also exercises a beneficial influence where scale forming feed water is used. The bicarbonates of lime and magnesia, which constitute the principal scale-forming constituents of most water supplies, are dissociated at temperatures of 200 degrees F., and above into carbonic acid gas and the insoluble mono-carbonates of lime and magnesia, with the result that a precipitate is formed which settles out of the water. If the water is heated in the economizer, a large part of this matter accumulates in the latter as a soft sludge, instead of being carried into the boilers, where it would bake onto the heating surfaces as a hard crust or scale, and while it is a difficult and expensive operation to clean boiler tubes, it is a comparatively simple matter to remove this deposit from the economizer.

The question of load in the steel plant is one which demands the use of an economizer. It is a well known fact that here the load is anything but constant. This is due to the fact that the operation of the rolling mills, and other mills, causes the load to fluctuate from very low to exceedingly high peaks, at periods which the power plant does not control. Although it is quite a difficult matter to reason out just what the effect of load variations is upon an economizer as a heat absorber, yet we do know that the operation of power plants, with such variable loads as are present in the steel mills, is anything else but economical. With these loads suddenly going off and coming on, the power plant regulation is greatly assisted by the use of an economizer. This acts as a large storage for hot water, which means that there is always a great quantity of hot water available, when it is needed by the boiler to meet the demand of any load conditions whatsoever, which the boiler is called upon to perform. Suppose it were possible to install an economizer in conjunction with a boiler in such a manner that the economizer would be used simply as a storage for hot water, the temperature of which would be so close to the point where it would be converted into steam, that only a slight change in condition would bring this about. Then have the boiler of the so-called "flash" type whose function merely would be that of quickly changing this water into steam in quantities sufficient to meet the load demands. The boiler then would not have to be as large as under ordinary conditions and we would find that the installation cost would be cheapened due to the fact that the price per square foot of heating surface of an economizer is less than that of a boiler. The conditions, as stated, though, are only ideal, but this tends to illustrate the value of the economizer as a storage for hot water.

We find in the steel mill power plants as well as in most all power plants which are called upon to carry heavy loads that there is a great tendency to operate these plants at very high pressures. This being the case the gases leaving the boilers are going to be correspondingly higher than under ordinary operating pressures. Here, again, we find an excellent condition for the economizer installation. As has already been stated the addition of boiler surface to take care of a greater rate of absorption when operating at high pressures would not be as profitable as adding surface in the form of an economizer.

Another problem, which must be solved, is the question of high ratings. In steel mill power plants, the tendency is becoming stronger and stronger to operate at high ratings. The engineers in charge are forced to resort to, and, accordingly, must demand high ratings. Immediately this will abolish the question of natural draft, the alternative being an induced draft equipment with a stack temperature of perhaps 650 degrees to 700 degrees or possibly more. This signifies that a very large volume of gas will be given off in the exit from the boilers. Accordingly, the induced draft fan must be correspondingly large to handle this volume of gas, at these high temperatures and, naturally, this gas will pass off into the air carrying with it an enormous amount of heat which should be utilized instead of being wasted. This is a very undesirable condition. On the other hand, by the introduction of an economizer in the path of these hot gases, we find that there would be a great reduction in the temperature and likewise in the volume of the gas to be handled by the induced draft equipment. Since this would be the case, it is evident that an appreciable saving would be realized in the cost of the induced draft fan, due to the fact that a smaller unit could be installed, which would be sufficient to handle the smaller volume of gas leaving the boiler. Hence, it is plain to see that an economizer installation would greatly improve the undesirable conditions which are produced when operating at high ratings. Furthermore, the economizer appears to open up the way for greater developments in the field of steel mill power plant operation at high ratings.

Considerable discussion has been entered into by various engineers regarding the installation of economizers on waste heat propositions. As is well known, the gases leaving the open hearth furnaces, in the steel mills are of temperatures ranging anywhere from 1,000 degrees to 1,500 degrees or so. If a waste heat boiler is used in connection with the open hearth furnace, the gases leaving the boiler are usually in the neighborhood of 500 degrees to 600 degrees or more. These temperatures are approximately the same as would be obtained in ordinary practice with a coal fired boiler, at which temperatures an economizer could be installed to afford an increase of capacity. If a careful survey of waste heat boilers in steel plants is made, you will readily understand why some engineers do not prefer to install an economizer with a boiler of this type. By actual test it has been discovered that most of the waste heat boiler installations have been such that they permit an enormous amount of air infiltration. This, of course, tends to reduce the gas temperatures as well as decrease the capacity of the boiler, hence to actually decide whether the conditions will warrant an economizer installation, it is highly essential that the minimum air leakage possible be obtained before any conclusion re-

garding the existing conditions is formed. If this is done the draft loss through the boiler will be minimized, and surprisingly enormous gains will be secured.

In Scotland, there are a number of economizers installed in connection with waste heat boilers using the gases from open hearth furnaces. The installations have been, from every point of view, an eminent success. No difficulty has been experienced with explosions—the flue work and setting of both boilers and economizers having been amply provided with explosion doors. It would hardly appear possible for explosions to occur in the economizers anyway as the temperature of the gases is considerably lower than that of the ignition temperature. These installations have aroused a great deal of English interest and recently quite some activity has been shown in this country along these lines.

In the olden days when the amount of blast furnace gas available was sufficient to meet the power requirements in the steel plants, the question of an economizer was of no avail. But in the present day operation we find that the power requirements far exceed the supply of the blast furnace gas and as a result coal has been the next leading fuel. Consequently the power plants were designed to use this type of fuel. Owing to the fact that the price of coal is rapidly advancing, the question of an economizer installation again presents itself as a means of fuel saving.

Thus, the installation of economizers in steel mill power plants should be regarded as a necessity. Any power plant operation, at high ratings as well as at high pressures, is bound to lower the efficiency of the boiler. Since the steel mill power plant engineers are compelled to operate at high ratings and pressures, it follows that any economizer installation will be of greater value, the lower the boiler efficiency. Steel mill power plant operation is subject to variable loads, and naturally the saving in fuel, which an economizer will afford, will be proportional to the load factor. The question of saving in cost is, therefore, obvious.

USE OF LARGE TURBINES IN THE STEEL INDUSTRY.

(Continued from page 356)

and the installation of turbines capable of utilizing the steam thus rendered available, would meet all power demands for the mill itself and have a surplus amount of power for sale as a by-product.

The steel mills already sell by-product cement, benzol, fertilizer, etc., so that it would not be a radical departure to sell one more commodity and the market exists at the doors of the steel plants. Probably arrangements, satisfactory to both parties, could be made to tie in with the lines of the public utilities supplying the neighborhood. Such a plan would help conserve the natural resources of the country and help fulfill its industrial requirements.

In the past, when the generation of power has been incidental, too little attention has been given in some cases to the careful and skillful operation of turbines installed in steel mills. This is a point which is now receiving more attention but if the generation of power becomes a producer of revenue, one of the beneficial results will probably be to impress the operating force with the importance of their work. Intelligent and efficient operation is the source of reliability.

Use of Large Turbines in the Steel Industry

Increase of Large Turbines in Steel Mills—In Steel Mills
Turbine Capacities Have Increased From Approximately
1,500 kilowatts to 20,000 kilowatts.

By H. C. FAIRBANK.

THE term "large turbine" has changed in its meaning. In 1903 the largest turbine installed in this country was rated 5,000 kw. The largest single cylinder turbine with a single generator today is rated 50,000 kw. In steel mills turbine capacities have increased from approximately 1,500 kw to 15,000 kw and 20,000 kw capacity. This increase in turbine capacity of course is due to the increased use of electricity through the steel plant, particularly for main roll drives and their auxiliaries.

As steam driven mills were changed over to electric drive, the tendency at first was to install turbine capacity to meet the anticipated electric load, with perhaps a duplicate unit as a spare. When additional mills were electrified perhaps a turbine of capacity great enough to carry the total load of the plant was installed; the older turbines being held in reserve.

The steam pressure was usually limited to the operating pressure on the engines. Although the economic advantage of higher pressures for the turbines was recognized, there was considerable reluctance to the use of more than one steam pressure in the mills. Now the

tendency is toward the installation of central power stations in the steel mills, with new boiler plants designed for pressure from 200 to 250 pounds or higher.

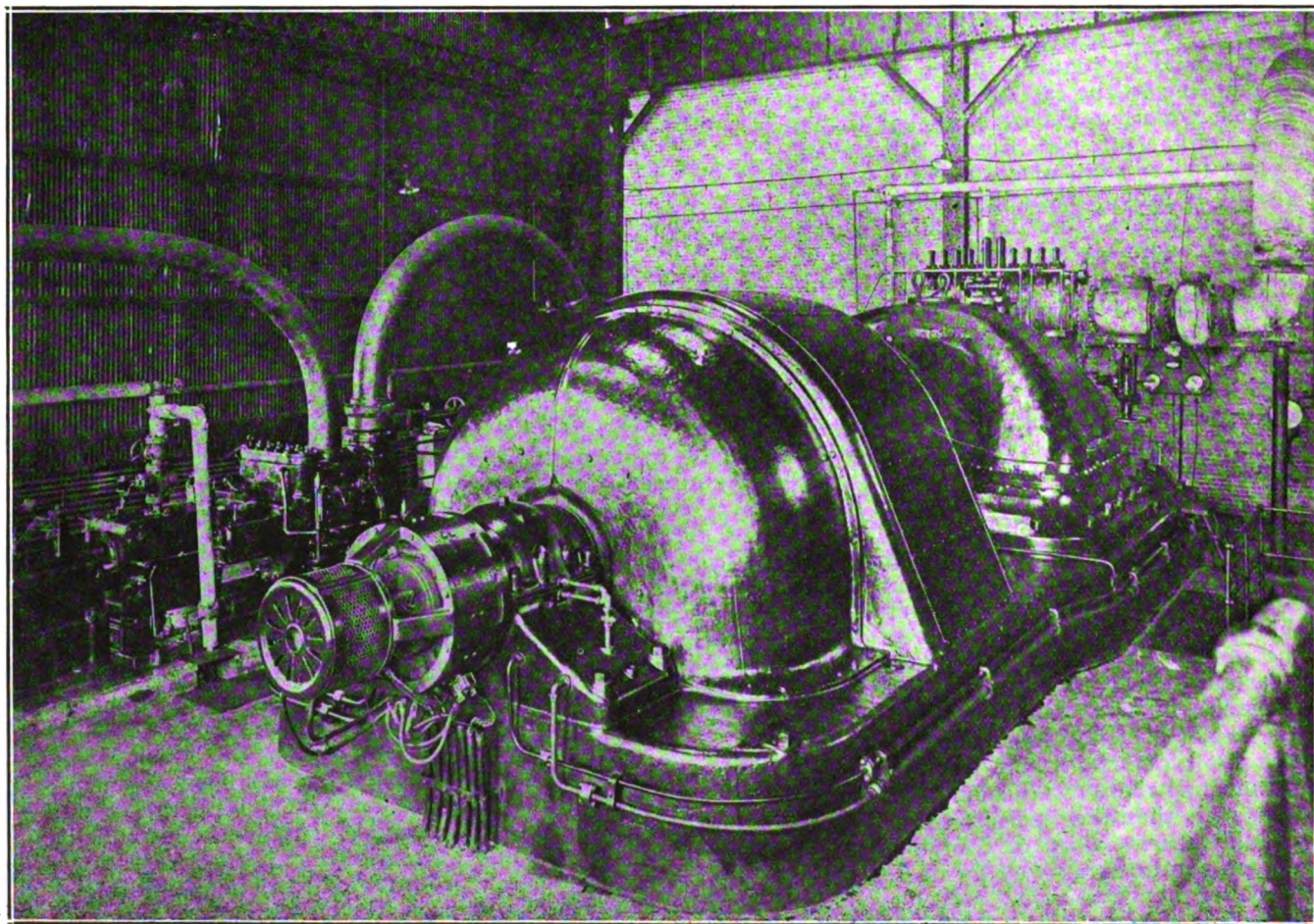
Inasmuch as these boilers are operated separately from the boilers supplying steam to the engines, advantage is taken of the economic possibilities of superheated steam.

Among the factors which should be considered in determining the size of units for any proposed installation are the increasing fuel costs and the power shortage in nearly all industrial centers.

The attention of the management of a steel plant is largely fixed upon the production of pig iron and steel. The question of the production of electricity and the utilization of the available heat units is secondary. However, the savings which can be made over existing practice are so great that they warrant giving this question the utmost consideration.

The installation of waste heat boilers on open hearth and heating furnaces, the burning of by-product gas and blast furnace gas under modern boilers,

(Continued on page 355)



Large General Electric turbo-generator installed at the Jones & Laughlin Steel Company, Woodlawn, Pa.

New Small Type Turbine for Steel Plants

Development of Small Mill Type Turbine for Steel Mill Use Which Is Ruggedly Built and Has Economical Steam Consumption.

By R. M. RUSH,

President, The Rush Machinery Company.

SMALL steam turbines may be made in a number of ways. In the past they have usually been made to suit the turbine manufacturer. This article deals with a small steam turbine designed and manufactured to suit the steel mill operator.

Electric motors so built have long been known as "mill type" motors. In fact, we have "mill type" magnets, cranes and other apparatus in common use in steel mills, but heretofore no effort has been made to place in commercial use a steam turbine answering that description. The first requirement of such a machine is that it give uninterrupted service regardless of the operating conditions. Linked with this is freedom from repair charges over a long period of time. The other requirement is that the turbine be economical.

There is no longer any mystery regarding what steam consumption can be obtained with given blade velocities, wheel diameters, and steam pressures. Bucket and nozzle angles may affect the result a little, but these are so well known to turbine designers today that they cannot enter into the problem. A velocity stage turbine with wheels large enough to make the steam velocity and the bucket velocity bear their correct relation, is admitted to be the most economical type of turbine for non-condensing service. A three-row Curtis with buckets enlarging to accommodate the expanding jet of steam will, generally speaking, use from 10 to 25 per cent less steam at favorable speeds, than any other type of non-condensing turbine. With steam costs rapidly mounting in every steel mill it is obviously this type that should have the favorable consideration of the steel works steam engineer.

Various ingenious devices have been developed in the past for cheapening velocity stage turbine manufacture. Chief among these have been the attempts to make one turbine wheel with one row of buckets take the place of three. Obviously this makes a cheap and simple turbine and in the days when steam was produced for 15 cents a thousand pounds its use was well justified. With

steam costing more every day, a saving of 10 per cent in steam consumption will soon pay for an economical steam turbine. Other attempts to cheapen turbine manufacture have been the elimination of various necessary parts of the turbine such as bearings, governors, etc. While it is quite possible to build and operate turbines of very small power with only one bearing, in the larger sizes, wheels must have sufficient diameter to give efficient bucket speeds and conservative design demands two bearings supporting a stiff shaft. It is thus

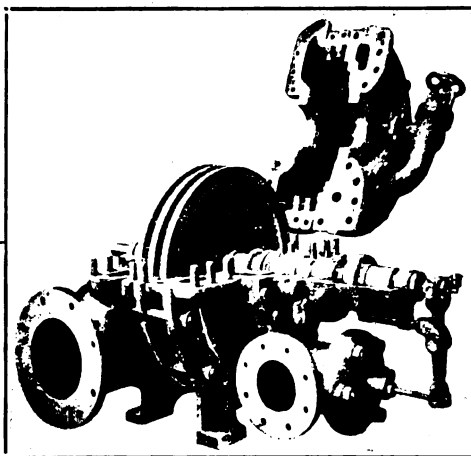
evident that the three-row Curtis turbine with wheels large enough to give highest steam economy, shaft stiff enough to support these wheels and two bearings large enough to support this shaft, must be the basis for a true "Mill Type" turbine. The type of turbine used

most generally was a fragile, high speed machine which eventually resulted in turbines being condemned by mill operators as unreliable. The tendency then was to use types that were first of all reliable but not necessarily economical. With rising steam costs the question of economy is being more and more emphasized and there has been an insistent demand for a turbine that would prove both economical of steam and thoroughly reliable. In other words, there has been until recently an unsatisfied demand for a "Mill Type" of steam turbine.

The accompanying photograph shows a 100 hp "Mill Type" non-condensing turbine with its casing on and with the top half lifted. This photograph tells graphically the story of the productive methods which makes possible

the marketing of a "Mill Type" turbine. Anyone familiar with the small turbine business is fully aware that no two sets of conditions are alike. In the electrical business voltages, cycles and speeds are pretty well standardized. The small turbine designer, however, must be prepared for steam pressures of from 80 to 350 lbs. and terminal pressures of from 50 lbs. back pressure to 29 inch vacuum. Speeds and horsepower vary with equal facility.

The natural result has been that most turbines are designed for an ideal set of conditions and for any other



About 10 years ago steam turbine driven pumps, generators and fans were quite rapidly installed to replace reciprocating units. The principal reason for this was their better steam economy. The type of turbine used most generally was a fragile, high speed machine which eventually resulted in turbines being condemned by mill operators as unreliable. The tendency then was to use types that were first of all reliable but not necessarily economical. With rising steam costs the question of economy is being more and more emphasized and there has been an insistent demand for a turbine that would prove both economical of steam and thoroughly reliable. In other words, there has been until recently an unsatisfied demand for a "Mill Type" of steam turbine.

set a compromise must be effected. With the Kerr sectional casing the proper number of stages can be added to make any particular turbine the right turbine for the job it has to do. Rateau stages, which are more economical for the vacuum end of the turbine, can be added for the particular vacuum it is desired to carry, and all of this can be done with standard stock turbine parts.

A brief description of the turbine is in order. The buckets are of nickel steel drop forgings, carefully heat treated. During the war a large number of turbines were built for ship propulsion. Forged buckets were used in a great many of these and a system of heat-treatment for buckets was developed which made them strong and tough, and at the same time left a hard skin on them that resisted erosion. The buckets are fastened to the wheels with bulb shanks that make it impossible to pull them out. The first experimental turbines of this type were installed nearly two years ago and inspection shows not the slightest sign of bucket wear or erosion.

Carbon packing of a special kind is used to prevent steam leakage at the shaft. In the old Rateau type of turbine where steam under high pressure was employed inside the turbine casing, carbon packing was a great source of annoyance. In the "Mill Type" of turbine two things have been done to eliminate this trouble. First of all the steam does not enter the casing under pressure, but expands from steam chest pressure to about atmosphere in the first set of nozzles. The second point is that a new kind of carbon ring has been developed that is non-breakable and practically non-destructible. If fragile carbon rings were able to hold steam pressures of 200 pounds in the Rateau type of turbine, an equal number of better rings will eliminate any trace of leakage with the low pressure inside the casing of the "Mill Type" turbine.

The governor is of the standard direct connected

type for small machines and the same type operating an oil pilot valve to actuate a piston in a cylinder in the larger turbines. A Schutte & Koerting trip and throttle valve with remote control, solenoid operated, can be furnished to trip with even the smallest turbines. Usually separate trip and throttle valves are not furnished with any except large turbines, but the safety engineers of the steel mills are demanding better emergency governor and trip valves even on small turbines.

A special type of overload valve has been developed for the "Mill Type" turbine. It makes use of the well known principle of turbine operation that the steam pressure below the governor valve varies directly with the load. As the load reaches 100 per cent the governor valve opens wide and the steam chest pressure is practically line pressure. When such a condition occurs, additional nozzles are automatically opened by the overload valve.

This overload valve will open in case of low steam pressure, drop in vacuum or increased load. It is particularly desirable in mill service pump drive, where it is necessary to keep the pump running under any condition. This valve is furnished as special equipment. One was recently furnished with a 700 hp condensing turbine that enabled the turbine to develop full load automatically upon failure of the condenser and upon drop in steam pressure to 90 pounds. It will keep the mill service pump going as long as there is steam in the boilers.

The question of a mill type of steam turbine has been discussed with the chief engineers, master mechanics and managers of a great many steel plants. The consensus of opinion, as the writer has found it, is that such a machine fills a definite demand.

Twin Tandem Compound Reversing Engine

United Engineering and Foundry Company Builds Reversing Steam Engine to Drive New Forty Inch Blooming Mill at Weirton Steel Company.

By W. W. McBANE.

THE UNITED ENGINEERING & FOUNDRY CO. is just completing a 42 inch and 66 by 60 inch twin tandem compound reversing engine for the Weirton Steel Company. The engine is to drive a new 40 inch blooming mill.

Fig. 1, which shows a prospective view of the engine shows its simple rigid massive construction. The working steam pressure will be 225 pounds per square inch with 125 degrees F. superheat, and the exhaust will be connected to a 108 inch barometric condenser. The crankshaft has four bearings. The main bearings have cast steel caps, quarter boxes and bottom shells. The main bedplates or frames are of the simplest possible outline of the bored guide type arranged as far as possible for the working strains to act in straight lines. The low pressure cylinders are attached directly to the bedplates and the high pressure cylinders are attached to the low pressure cylinders through single piece cylindrical distance pieces which are provided with guides for the intermediate sliding heads. The main crosshead and intermediate and rear sliding head shoes are arranged for wedge adjustment. The back end of the low pressure and

both ends of the high pressure cylinders are carried on flexible steel plates. This construction which is clearly shown by both Figs. 1 and 2, insures rigid alignment and at the same time provides for free expansion.

The entire design is of the simplest and most accessible possible, with a view to reducing to a minimum the number of moving parts, and assure continuous reliable service. The valve gear is of the Stephenson type with the eccentric rods connected directly to the low pressure valve stem crossheads. The low pressure and high pressure valves are of the tubular piston type with both valve stems directly in line. This arrangement gives a straight line pull from the eccentrics to the valves and a minimum of connections to wear and cause lost motion. The link motion is operated by a steam cylinder checked by a water-cooled oil cylinder and controlled from the pulpit through a floating lever. The entire control of the engine is by a single lever.

The main steam connection as well as the exhaust from the engine is carried underneath the floor as shown by Fig. 2, thus eliminating the danger of the steam connections being wrecked by crane loads.

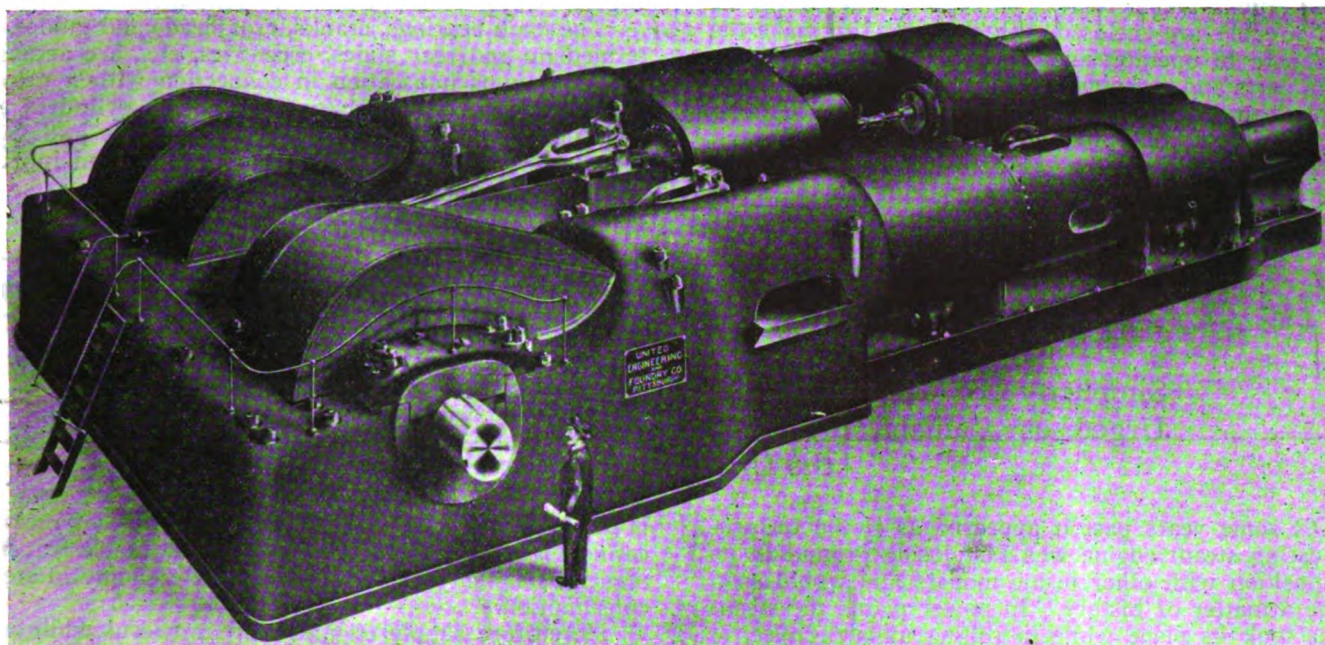


Fig. 1—Prospective view of engine showing its rigid massive construction.

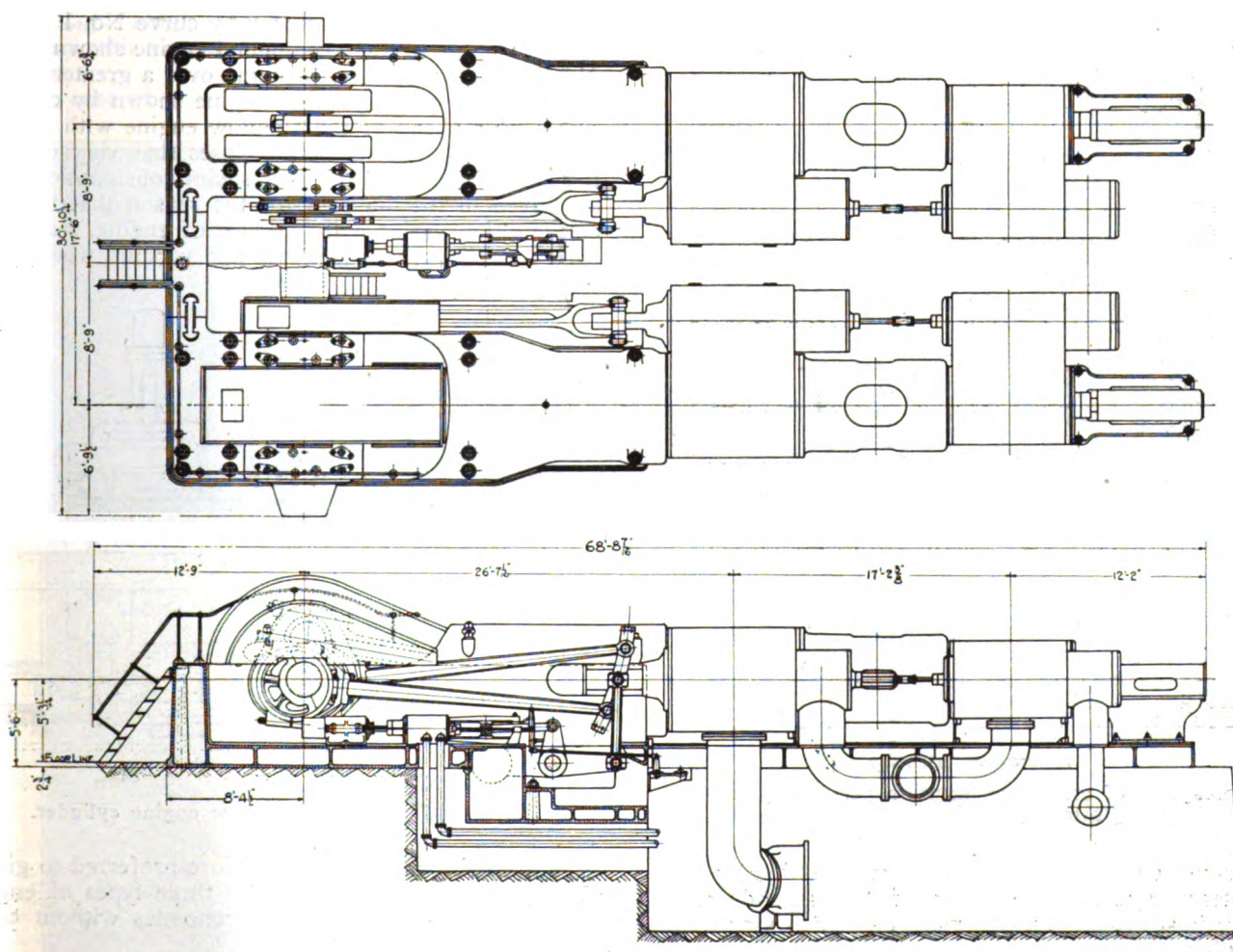


Fig. 2—Design of engine showing its steam connections.

The cranks and eccentrics and all moving parts, as far as possible, are enclosed with sheet steel to make the engine safe to operate, and prevent oil throwing from moving parts and escaping, so that the engine may easily be kept clean. Sheet steel guards are also provided along the eccentric rods on both sides of the engine to prevent oil escaping and also to make a safe passage through the center of the engine. This passage being on the same level the entire length of the engine. The plan view of

Fig. 2 clearly shows this arrangement.

The main bearings, cranks, crossheads and guides, intermediate and rear slides, eccentrics, etc., are arranged for continuous lubrication in connection with a gravity oiling system. The high pressure steam cylinders and high pressure and low pressure piston rods and valve stems are connected to Richardson sight feed lubricators. As far as possible, the valve gear parts are arranged for grease lubrication.

The Unatlow Engine as a Prime Mover

Simplicity of Construction and Economy in Steam Consumption Urged as Valuable Features in Favor of Extended Use of the Unatlow Engine.

FOR some years past it appeared as if the reciprocating steam engine was fast losing ground in its position with other prime movers and would soon become a matter of history. In power plants the steam turbine took its place while in rolling mills the electric motor was substituted. In recent years, however, en-

is the invention of Prof. Stumpf. This type of reciprocating engine combines two exceedingly valuable features, namely, simplicity in construction and economy in steam consumption.

Heretofore simple engines were wasteful while economical engines were expensive and complicated; furthermore, complicated multi-expansion engines of the old or "Watt" type are economical over a narrow range of load only, while the "Unatlow" or "Stumpf" type of engine is economical over a much wider range. The relation with respect to economy and range of load is illustrated by the following diagram.

The Unatlow engine shown by curve No. 1 is as economical as the average compound engine shown by curve No. 2, but sustains that economy over a greater range of load. The triple expansion engine shown by curve No. 3 is a little ahead of the Unatlow engine with regard to economy at rated load, but it loses that very quickly if the load changes. No actual steam consumption figures are given in the diagram for the reason that the steam consumption varies with the size of engine, steam pressure, superheat, back pressure and vacuum when operat-

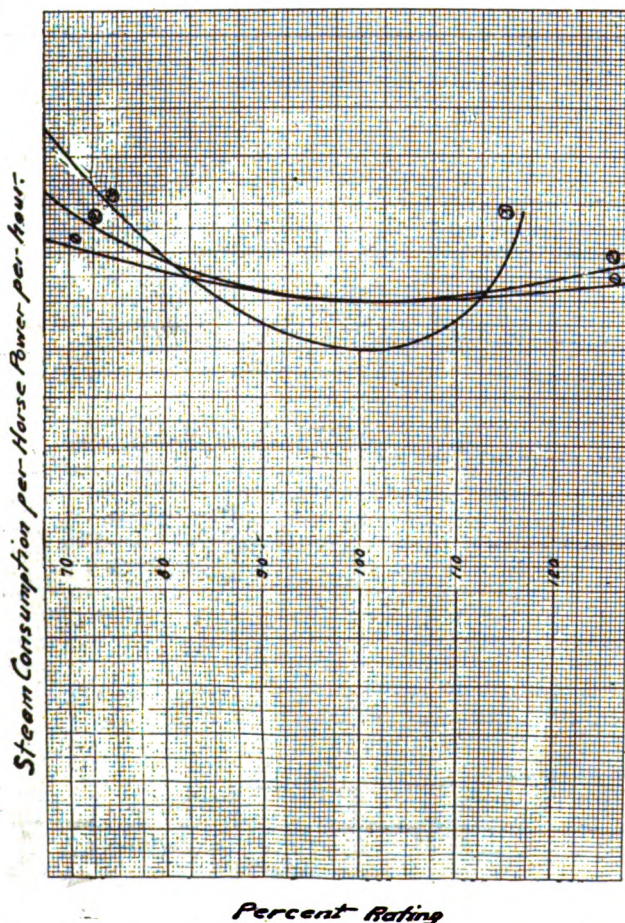


Fig. 1—Diagram of steam consumption per horsepower per hour plotted against per cent rating

gineers have come to the conclusion that the abandoning of the steam engine has been carried too far and from present indications the steam engine is again coming to the front.

This change in opinion has been largely brought about by the introduction of the Unatlow type of engine which

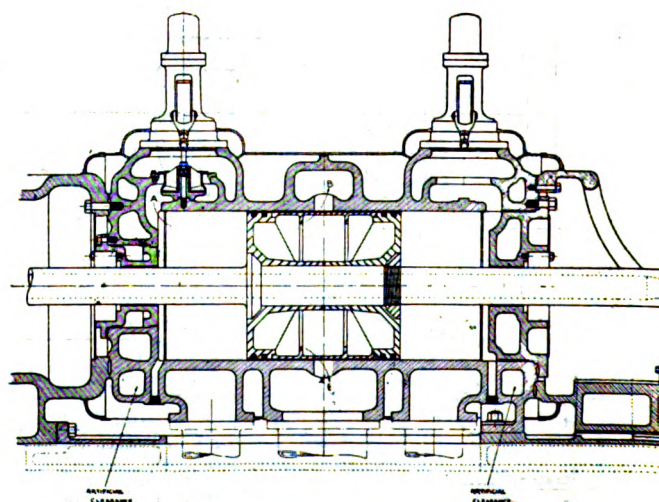


Fig. 2—Diagram of Unatlow engine cylinder.

ing condensing and it was therefore preferred to give an average relation diagram of the three types of engines, which will show the relative economies without confusion.

Those who are familiar with reciprocating steam engines know that internal cylinder condensation is the

greatest enemy of steam engine economy. A large part of the incoming steam condenses on the cold cylinder walls forming a thin film of water. A small part of this water re-evaporates during the expansion stroke, doing a small amount of work, but by far the largest portion of the water film flashes into steam when the exhaust valve is opened and passes into the exhaust port doing no work and at the same time cooling the cylinder walls, thus making them ready to condense steam again during the next working stroke.

If cylinder condensation can be eliminated, reciprocating steam engines will be more economical than steam turbines. While the Unaflow principle does not entirely eliminate cylinder condensation it does, however, reduce it by about 60 per cent of the whole amount and thereby produces an engine which is far ahead of the "Watt" or duoflow type of engine. The principle itself is very simple as shown by the following diagram.

The piston is made long so that it acts as an exhaust valve in connection with the exhaust port B at the center of the cylinder. The steam enters at A (cylinder end) and leaves at B (center of cylinder) whenever the piston has uncovered the port B. The cold exhaust steam does not flow over the cylinder ends and therefore does not carry off any heat, or in other words, the exhaust steam does not cool off the cylinder heads, steam inlet ports and the adjacent cylinder walls as happens with other types of engines, and therefore, any condensation of the incoming steam due to such causes is eliminated. Condensation on the cylinder heads and on the ends of the barrel during the compression stroke is prevented by jacketing. This jacketing is an important feature in connection with a central exhaust and is covered by a letter patent.

In case of loss of vacuum the inlet valves are lifted

by compression and make a fluttering noise which indicates that the condensing apparatus has ceased to function. Auxiliary clearance volumes are provided in the cylinder heads so that the clearance can be increased in order that the engines may have the proper compression when running non-condensing. The clearance valve is opened by means of a hand wheel and the change from condensing to non-condensing operation or vice versa is thus effected by the simplest means. There is no equally simple method in existence for the old duoflow type of engine or the steam turbine.

The Unaflow engine is invariably designed with poppet valves for steam inlet. This type of valve is not affected by superheated steam, whereas the time honored American Corliss valve is wholly unsuited for superheated steam. The Unaflow engine is, therefore, just as adaptable to modern power plant conditions as the steam turbine is, and perhaps more so, for the reason that Unaflow engines are now contemplated for usually high steam pressures and high superheats that are far beyond the range of the steam turbine.

With all of the advantages of the Unaflow engine it is not to be expected that it will in every case and everywhere compete with the steam turbine and electric motor; but there are many cases where the Unaflow engine is the only right solution; among such cases are the following:

- Power plant units that have to run non-condensing a considerable part of the time.
- Power plant units for direct current.
- Rolling mill engines for mills having waste heat boilers.
- Rolling mill engines for mills with central power stations having steam turbines of less than 10,000 kw capacity per unit.
- Rolling mills or power plants with warm or insufficient water for condensing purposes.

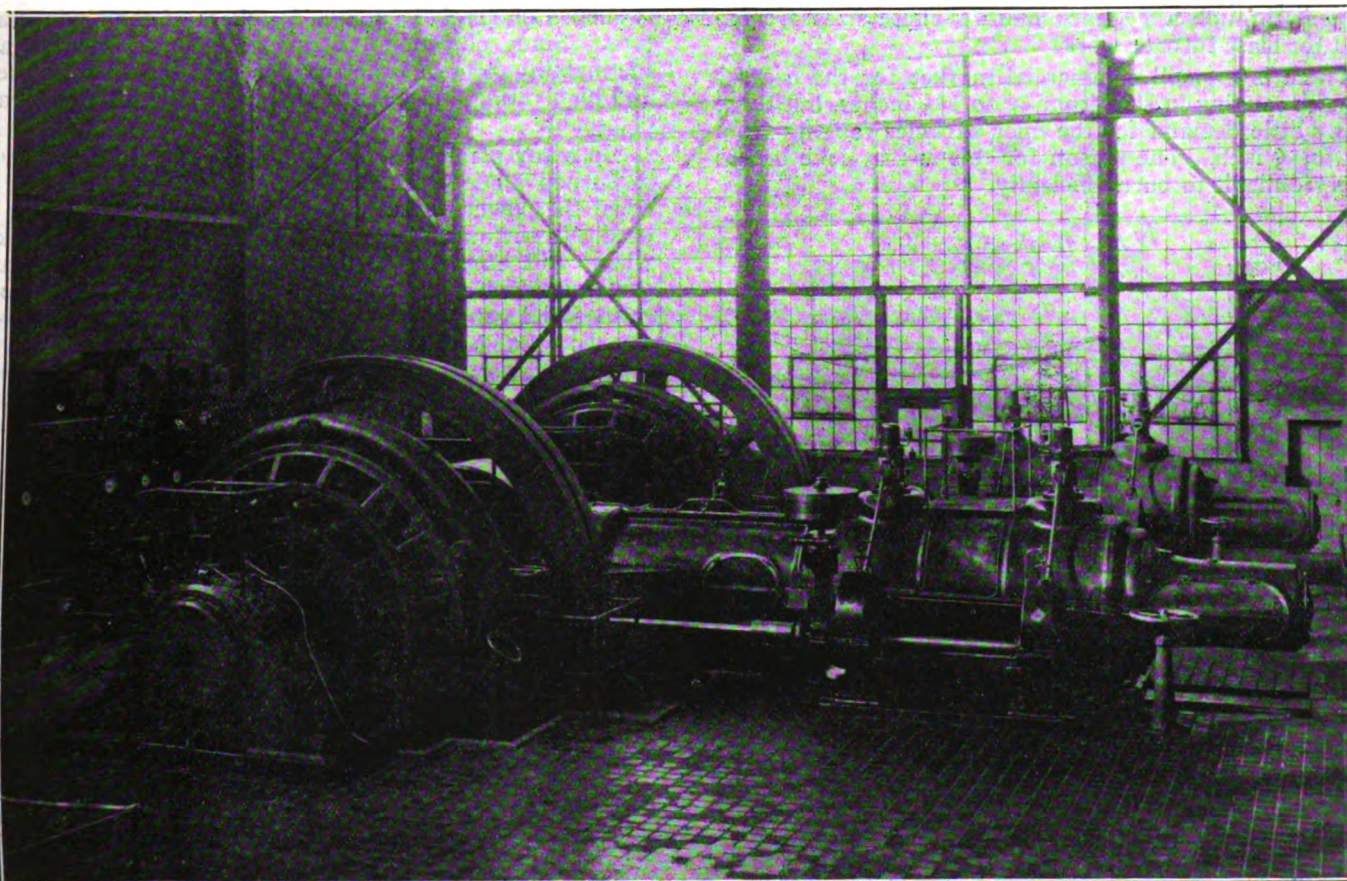


Fig. 3—Installation of two Unaflow engines each driving a 900 kw dc generator.

In all cases, mentioned above, the Unaflo engine will effect a considerable saving over any other type of prime mover used.

Mention might also be made of the fact that with the Unaflo engine, steam can readily be bled from the engine at any desired low pressure, for steam heating, drying, vulcanizing, etc., and very good overall efficiencies can be obtained by this method for varying demands of steam for heating or other manufacturing processes.

The simplicity in the construction of the Unaflo engine is equally as notable as its economy in operation. Due to the absence of exhaust valves, the valve gearing is confined to the two inlet valves which are operated by eccentrics from a lay shaft in much the same manner as the valve gearing of a gas engine is driven, excepting in the case of the gas engine the lay shaft must operate the exhaust valves as well as the inlet valves. The lay shaft is driven from the main shaft of the engine by means of

gears. A powerful and sensitive governor controls the lift of the inlet valves, or in other words, the amount of steam admitted to the cylinder and insures steady regulation. With high steam pressures the superheat, a steam consumption as low as 10 pounds per ihp per hour is readily obtained in condensing operation. Due to its uniformly high economy and simplicity of construction, the Unaflo engine is ideal for rolling mill service.

The Stumpf Unaflo Engine Company, whose patents have been sustained through all the courts of the United States, has licensed the Mesta Machine Company to manufacture the Stumpf Unaflo Engine under their patents, and has granted them the exclusive right to build this type of engine for rolling mill service.

The illustration, page 361, shows two Unaflo engines installed in the power plant of the Mesta Machine Company, each driving a 900 kw direct current generator.

Burning Coke Breeze on Underfeed Stokers

This Article Deals With Metallurgical Coke Such as Is Used in Blast Furnaces—Metallurgical Coke Is Harder to Ignite and Burns More Slowly Than Gas Coke.

By F. A. DE BOOS

The Underfeed Stoker Company of America.

IN the manufacture of coke there results a considerable accumulation of fine abrasions amounting to approximately 6 per cent of the total coke produced. These fine abrasions are termed coke breeze, and in general 40 per cent will pass through a $\frac{1}{2}$ -inch mesh screen, and 60 per cent through a $1\frac{1}{8}$ -inch mesh. These sizes are too small for blast-furnace work.

There is a small commercial market for the coarser particles ranging in size from $\frac{3}{8}$ to $1\frac{1}{8}$ inches, but there is very little demand for the finer particles ranging from dust to $\frac{3}{8}$ inch. The reason for this is that coke breeze is very difficult to burn efficiently.

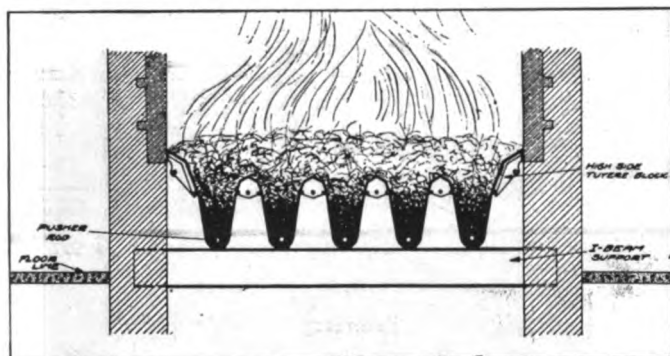


Fig. 1—Vertical cross section of five retort Jones A-C stoker burning mixture of three parts coke breeze and one part coal.

It has a good heating value. The Btu content on a dry basis averaging approximately 10,000 to 11,000. Approximate analysis of the coke breeze will vary, as follows:

	Per cent	Per cent
Fixed carbon	60	75
Volatile	5	8
Ash	15	22
Moisture	4	20

In many plants the coke breeze accumulation is thrown away. In others it is hand fired in connection with coal. The objections to this method of disposal are the labor involved, low efficiency secured and the inability to obtain high boiler ratings. In some plants coke breeze is burned on specially designed stokers of the chain grate type. Some objections to this method of disposal are the inability to burn either coal or coke breeze as desired, and high rating and flexible operation are, in general, not obtainable.

In many plants the accumulation of coke breeze, even if burned alone with fair efficiency is not sufficient to equal the power demands, and coal fired boilers must be used. In such installations there is a demand for a stoker which will burn varying mixtures of coke breeze and coal and which will have the ability not only to give good ratings and good efficiencies with such mixtures, but will also be capable of securing extremely high ratings with proper efficiencies when burning all coal. The stoker should also be so constructed that it will quickly adapt itself to either pure coal or coke breeze mixtures without any change in the mechanism.

The perfect stoker, of course, would be one that could secure high ratings and high efficiencies out of pure coke breeze, coke breeze and coal mixtures or all coal. It is doubtful if such equipment can be designed as the requirements for burning pure coke breeze are altogether different from those necessary for burning coal.

The main requirements for burning coke breeze and coal mixtures are, as follows:

First—The mixing mechanism must be simple in order to accommodate conditions in existing plants.

Second—Coke breeze mixtures must be held together so that the particles of coke may "freeze," thus permitting the air pressure to facilitate combustion. Holes in the fire and slippage of the fuel bed must be avoided.

Third—The fuel bed should be kept fairly thin as otherwise heavy clinkers will develop, necessitating high air pressure.

RESULTS OF BOILER TRIAL.

The following shows the results of a boiler trial made at the Michigan Limestone and Chemical Company, Rogers City, Mich., December 4, 1919. The object of the test was to determine data on burning a mixture of one part coal and three parts coke breeze, 100 pounds coal to 325 pounds coke was used:

Boiler	Stirling
Rated hp	294
Stokers	Type A.C.
No. of retorts	3

Conditions.

Duration, hours	8.0
Steam pressure, lbs. guage	148.2
Temperature of feed water, degrees F.	179.9
Temperature of escaping gases, degrees F.	594
Pressure in air chamber, inches	2.8
Draft in furnace, inches	.15
Draft between damper and boiler, inches	.33

Flue Gas Analysis.

Carbon dioxide (CO ₂) per cent.	12.4
Oxygen (O) per cent.	7.8
Carbon monoxide (CO) per cent.	.0
Weight coal as fired, lbs.	4,550
Weight coke breeze fired, lbs.	14,785

Coal.

Total weight as fired, lbs.	19,335
Total weight water fed to boiler, lbs.	106,068
Factor of evaporation	1.079
Total equivalent evaporation F. & A., 212° F, lbs.	114,487

Analysis of Mixture as Fired.

Fixed carbon, per cent.	59.06
Volatile matter, per cent.	10.67
Ash, per cent.	15.36
Moisture, per cent.	14.91
Sulphur (Sep. Det.), per cent.	1.01
Btu per lb. dry	11,413
Btu per lb. as fired, per cent.	9,709

Analysis as Fired.

	Coal	Coke
Fixed carbon	55.80	60.06
Volatile matter	29.25	4.95
Ash	8.45	17.49
Moisture	6.50	17.50
	100.00	100.00
Sulphur	1.59	0.83
Btu.	12,856	8,741

Summary.

Coal burned per hour as fired, lbs.	2,417.0
Coal burned per hour per retort, lbs.	806
Water evaporated from and at 212° per hour, lbs.	14,310.9
Boiler horsepower developed (average) B.H.P.	414.7
Per cent of rated capacity developed.	141.1
Water evaporated actual per lb. coal as fired, lbs.	5.49
Water evaporated from and at 212° F. per lb. of coal as fired, lbs.	5.92
Water evaporated from and at 212° F. per lb. of coal dry, lbs.	6.96
Water evaporated from and at 212° F. per lb. of coal, combustible	8.49
Efficiency of boiler, furnaces and grate, per cent.	59.1
Ratio of coke to total fuel—as fired.	76.5

RESULTS OF BOILER TRIAL.

The following shows the results of a boiler trial made at the Michigan Limestone and Chemical Company, Rogers City, Mich., December 4, 1919. The object of the test was to determine data on burning a mixture of one part coal and two parts coke breeze, 100 pounds of coal to 225 pounds of coke was used:

Boiler	Stirling
Rated H.P.	294
Stokers	Type A.C.
No. of retorts	3

Conditions.

Duration, hours	8.0
Steam pressure, lbs. gauge	149.6
Temperature of feed water, degrees F.	168.8
Temperature of escaping gases, degrees F.	608
Pressure in air chamber, inches	2.7
Draft in furnace, inches	.14
Draft between damper and boiler, inches	.28

Flue Gas Analysis.

Carbon dioxide (CO ₂) per cent.	12.2
Oxygen (O) per cent.	7.6
Carbon monoxide (CO) per cent.	.0
Coal weight as fired, lbs.	5,800
Coke weight as fired, lbs.	13,050

Coal.

Total weight as fired, lbs.	18,850
Total weight water fed to boiler, lbs.	115,889
Factor of evaporation	1.090
Total equivalent F. & S. 212° F., lbs.	126,319

Analysis of Mixture as Fired.

Fixed carbon, per cent.	56.98
Volatile matter, per cent.	13.62
Ash, per cent.	13.82
Moisture, per cent.	15.58
Sulphur (Sep. Det.) per cent.	1.04
Btu per lb. dry	11,738
Btu per lb. as fired	9,909

Analysis as Fired.

	Coal	Coke
Fixed carbon	53.15	58.68
Volatile matter	33.39	4.84
Ash	6.46	17.08
Moisture	7.00	19.40
	100.00	100.00
Sulphur	1.56	0.81
Btu as fired	12,968	8,549

Summary.

Coal burned per hour as fired, lbs.	2,356
Coal burned per hour per retort, lbs.	785
Water evaporated from and at 212° per hour, lbs.	15,789.9
Boiler horsepower developed (average) B.H.P.	457.1
Per cent of rated capacity developed.	155.5
Water evaporated actual per lb. coal as fired, lbs.	6.15
Water evaporated from and at 212° F. per lb. of coal as fired	6.70
Water evaporated from and at 212° F. per lb. of coal dry	7.94
Water evaporated from and at 212° F. per lb of combustible	9.49
Efficiency of boiler, furnaces and grate, per cent.	65.6
Ratio of coke to total fuel as fired.	69.2

Fourth—Light air pressure is necessary as otherwise the fine particles of breeze are blown up into the baffling of the boiler or down onto the dump plate and holes in the fire develop.

Fifth—The slope of the fuel bed should be slight as otherwise the coke breeze will accumulate thickly at the rear of the furnace, necessitating a great amount of burning on the dump plate, causing large clinker formation.

Sixth—Due to the abrasive nature of the coke breeze moving parts are not desirable. Also the stoker construction should be such as to avoid an excessive amount of siftings dropping through into the air chamber.

Seventh—As coal and coke pockets may form in the hopper, causing an uneven fire in the furnace, flexible control of retorts, permitting variable speeds of the ram are desirable.

Below are given results of tests made at the Michigan Limestone & Chemical Co., Rogers City, Mich. The stokers used were the Jones A-C multiple retort type. A

24 hours a day, seven days a week, with variable loads, ranging from 150 to 250 per cent of rating.

During the summer of 1919, tests were also made by the Ford Motor Company to determine the feasibility of burning various mixtures of coke breeze and coal. The Semet-Solvay coke breeze burned was from the new Ford steel plant and ranged in size from dust to $\frac{3}{8}$ inch. A mixture of two parts coke breeze to one part coal was first used, and the mixture was then changed to three parts coke breeze to one part coal, and as a result of these tests, Mr. Charles Koehler, chief engineer, Ford Hospital, Detroit, Mich., is now burning a mixture of two parts coke breeze and one part coal very successfully and at a considerable financial saving. The coke breeze is stored in a bin separate from the coal and the charge is mixed

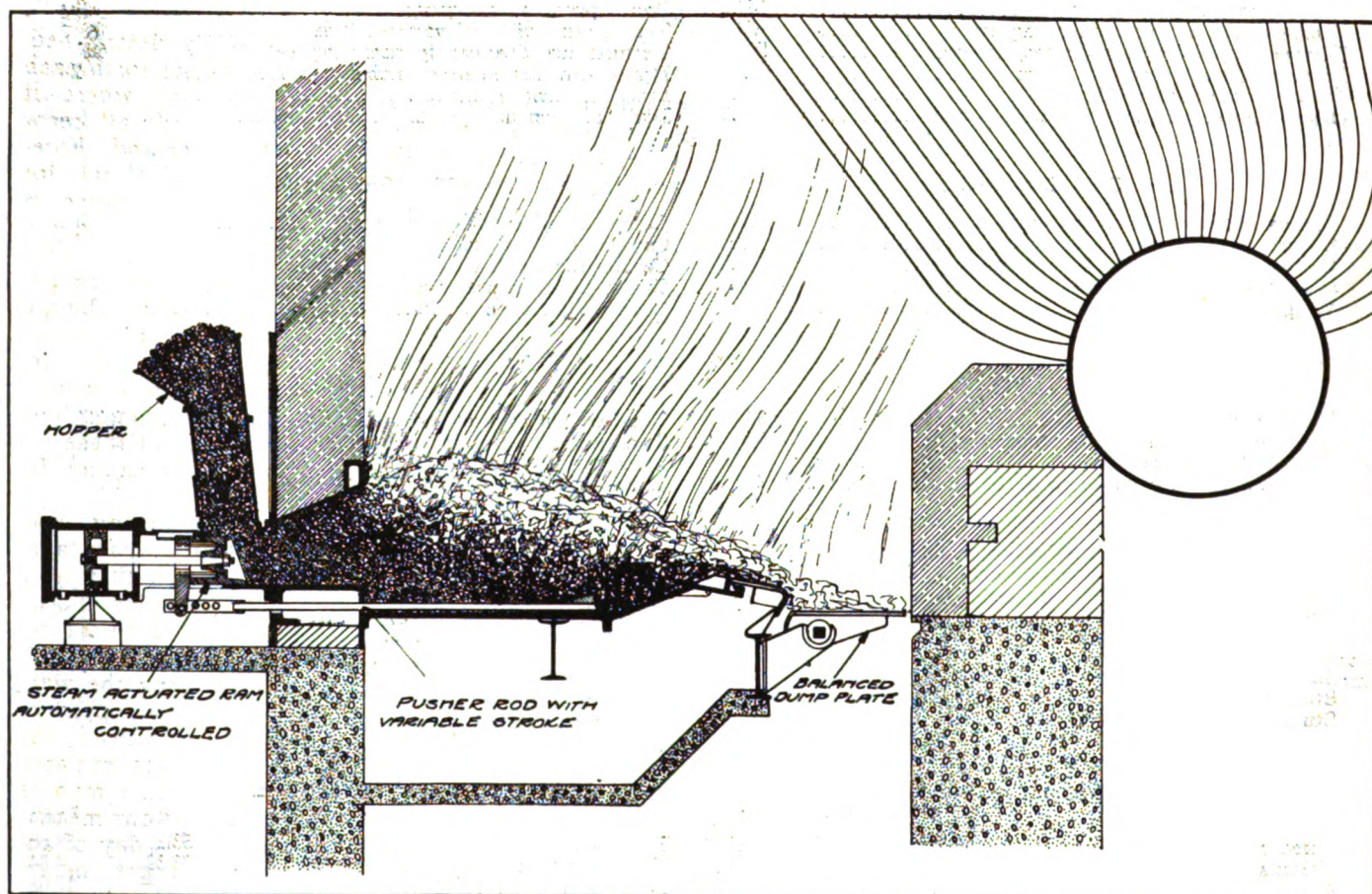


Fig. 2—Longitudinal section Jones A-C stoker burning mixture of three parts coke breeze and one part coal.

mixture of 225 pounds of coke breeze to 100 pounds of coal was burned with an efficiency of 65.6 per cent at 155.5 per cent rating. Also with a mixture of 325 pounds coke breeze to 100 pounds coal, 141.1 per cent rating was developed with 59.1 per cent efficiency. The accompanying illustration shows the fuel bed, arrangement of stoker, etc.

These tests were witnessed by engineers prominent in the steel industry, who were favorably impressed with the results secured.

The coke and coal were weighed separately and mixed with shovels, then fed into the hoppers. The coke breeze ran from dust to $\frac{3}{8}$ inch. The stoker had been in operation under the boiler for approximately three years and no changes were made in any way to facilitate the burning of the mixture. The boiler had been on the line for five weeks at the time the tests were made and operated

by dropping alternate charges of coke breeze and coal into a traveling bin. The mixture then descends through a short chute into the hopper of the stoker.

It is the intention of the Ford Motor Company to burn coke breeze mixtures at their new River Rouge, Detroit, steel plant, under four boilers now being equipped with these stokers.

The tests made at the Michigan Limestone & Chemical Co., and also at the Ford hospital, were conducted on stokers having an inside furnace length of 8 feet 7 inches. No extra air openings were made in the tuyere blocks. Much better results could, no doubt, be secured on a longer stoker having an inside furnace length of 10 feet 4 inches. Also by making more openings in the tuyere blocks a greater volume of air could be introduced at a lower pressure, which would tend to materially increase efficiencies and ratings.

Industrial Demand for Oil as a Fuel

The First Three Months of 1920 Have Established a Rate of Domestic Production That if Unchecked Will Reach a Total of Four Hundred and Fifteen Million Barrels.

By GEORGE OTIS SMITH,
Director United States Geological Survey.

IN the chronology of industry the last 10 years might fully be called the petroleum decade. The growth of the automotive industry, spectacular as it has been, was made possible only by the ever-increasing supply of gasoline. In the terrible four years of war every new machine of destruction on land and sea, in the heavens above and the depths below, depended on American oil wells for motive power; and the peace demand for petroleum products has already overtopped the war peak.

In these 10 years the natural inclination of mankind to trust to the largeness of nature has found abundant incentive. In the summer of 1910, the Lakeview gusher in California, excited popular interest with its flow of 40,000 barrels a day, but just before the close of the same year this record was surpassed by that of a well in Mexico, the Potrero del Llano, No. 4, with a maximum flow of about 160,000 barrels a day, yet even this outburst of oil was exceeded five years later by another Mexican well, the Cerro Azul No. 4, whose measured flow was more than 260,000 barrels in 24 hours. These individual performances, together with the strikes at Cushing and Healdton, Okla., and the later oil booms in North Texas and Louisiana, all have increased the popular faith in the inexhaustible supplies of petroleum.

Ten years ago the wells of the United States were adding to our reserve stocks 15,000,000 barrels in the year; now the current is in the other direction, for in the last nine months our stored petroleum has been drawn upon to the extent of 15,000,000 barrels. In 1910 our imports of oil were an insignificant item, but in 1919 we were obliged to import nearly 47,000,000 barrels of crude oil more than we exported. Ten years ago Mexico was our customer for crude oil as well as for refinery products, but now we realize too keenly our dependence upon the Mexican wells; without the 6,500,000 barrels imported from Mexico in March our present situation would be indeed critical.

In terms of oil, then, the decade 1910-1919 is best described as a transition from over-supply to over-demand. And figures already available indicate that in both production and consumption the present year promises a record that will further emphasize this discordance between supply and demand. The first three months of 1920 have established a rate of domestic production that if unchecked will mean a total for the year of 415,000,000 barrels, or nearly twice the output of 1910, and a rate of consumption that would make the year's requirements more than 490,000,000 barrels, or one-seventh more than last year's consumption.

A few months ago I tried to visualize the torrent of oil consumed by the country in 1918 by pouring the 413,000,000 barrels over Niagara Falls, and I found that the oil supply of that year equalled the flow of waters from the Great Lakes, with their vast drainage

Paper read before seventeenth general meeting of the American Iron and Steel Institute.

basin, for three hours and four minutes; but already there is promise that the consumption of oil in the United States the present year must be likened to the flow of Niagara for three hours and 40 minutes. The vision of such a river of petroleum prompts the question, "What are we doing with our oil?"

Facts of consumption are not easily determined. Where our oil comes from is a matter set forth each month in our Geological Survey reports; where it goes is largely a matter of conjecture. We all know in a general way the different kinds of demand. Foremost among these is the ever-increasing thirst for gasoline by the automotive engine, whose name is legion; next is the larger use of fuel oil for steam making; then the universal need of all industry for lubricants; and finally, the many other uses for petroleum products, not less important, perhaps, though involving less volume, unless we except the accumulated demand for asphaltic oils for road construction. Industry's need of oil has become large, and in several items the demand for more oil is now insistent. The next question is one of the relative worth of these industrial needs. If every demand for oil cannot be met, which use is to be given priority?

The first official note of warning that demand was overtaking supply was sounded a dozen years ago, but only within the last few months has that note swollen into a chorus, and the reason for this chorus of alarm is evident. Rising prices have led to the re-discovery of the law of supply and demand, which was supposed to have been repealed during the war; a consumption curve that rises faster than a production curve is the graphic signal of danger ahead; the heavy draft now being made upon our accumulated stores of oil—more than 10 per cent gone in 9 months—tells the story that we are living beyond our means; and it all leads us to ask ourselves, in this day of apparent plenty, "Where will our children get the oil they need?"

The response that the petroleum industry has made to the pull of demand during the last few months may be taken by optimists as a measure of what we can expect in the future. An intensive drilling campaign has been the practical response to high prices for crude oil, just as the orgy of newspaper advertising of questionable oil stocks is the reflection of popular interest in the petroleum situation, but even the most wisely directed drilling can give only temporary relief; energetic pushing upward of the production curve only hastens the coming of the year when that curve must turn downward. How soon we may expect the peak of domestic production becomes a very practical question, inasmuch as no one can see any prospect of any let-up in demand.

The fuel reserves of a nation are no less essential to its future industrial welfare than the gold reserves are essential to its present financial stability, but once lowered these reserves of coal and oil in the ground

can never be replenished. The official estimate of less than 7,000,000,000 barrels of oil as the quantity remaining available in the ground in the United States is believed to be liberal, but even if we inflate such an estimate 25 per cent the indicated reserve is seen to be far from ample when we contemplate our probable consumption this year of nearly half a billion barrels of crude oil. The division of ultimate domestic supply by current demand is all too simple a sum in mental arithmetic.

An estimate of the petroleum resources of the world has just been published by the chief geologist of the United States Geological Survey, David White, and his figure of 60,000,000,000 barrels for the whole world is doubtless exact enough to enable us to see the oil situation of the United States in fairly true perspective. Using within our own borders fully half of the world's annual production of petroleum, we seem to possess only about one-seventh of what remains. This lack of national self-sufficiency in oil reserves may be expressed in another way; contrast the international position of the United States in respect to oil with its position in respect to coal. In the past 10 years our 6,000 to 7,000 coal mines have contributed 41 per cent of the world's output of coal. Our present estimates credit the United States with more than half of the world's coal reserves, so that if we are to think in world terms, the great tonnage of coal produced by this country each year represents less than our national share. But now consider the petroleum situation: In these 10 years our 140,000 to 200,000 oil wells have poured forth more than 61 per cent of the world's output, although we now believe that the United States possesses only about 12 per cent of the oil left to the world for its future use, so that in oil our nation is doing far more than its share.

When we come to consider substitutes for petroleum products, the capacity of your own steel industry for furnishing benzol and alcohol as by-products deserves first mention. I am informed by Mr. Walker, of the Steel Corporation, that plants now in operation and under construction have a capacity of 95,000,000 gallons a year, that is, if the output of light oils is converted into motor benzol. Such an annual contribution of less than 2,000,000 barrels, however, is equivalent to not much more than a week's output of gasoline as the refineries of the United States are now running. The recovery of alcohol from your coke ovens has not yet begun, but British experience seems to show that the maximum alcohol capacity of the coke ovens of the United States might be less than their benzol capacity. Apparently, then, the benzol and alcohol possibilities of the steel industry cannot be regarded as promising enough motor fuel even to meet the present increase in demand. It must be recognized, however, that this country, as the world's greatest consumer of coal, has not fairly begun by-product recovery. With the higher cost of coal and this increased demand for by-products more efficient practice must result in the natural course of economic events.

The oil-shale resources of our country must not be overlooked nor their national value under-estimated as a rear line of economic defense. As their oil content is fairly comparable with the petroleum reserves of the world, these shales furnish an effective guaranty against the United States going bone-dry as to oil, but the oil won from oil shales will not be labor-cheap like the petroleum now flowing from our

wells. As long as industry is short-handed it cannot look for relief from oil shale nor can it expect any return to low prices for utilizing this resource, however vast its extent; yet these western mountains of oil-shale stand as a visible promise that even when our underground reservoirs of petroleum are drained the United States will not be at the commercial mercy of any foreign power—not even if that power has been prompt to take advantage of the present opportunity to acquire a majority share in the world's oil resources. Still, even with the largest measure of optimism, backed up with our oil shales, we must face the contingency that the next generation of American business men may see their trade rivals across the Atlantic turning the wheels of industry and commerce with cheaper oil than is available in the American markets. Regard for the future, then, forces us to plan how to use less oil at home and how to acquire our share of the foreign supply.

It is high time for us to begin to weigh the essential uses of petroleum. Oil was first used as an illuminant, but today, whether in the kerosene lamp on the modern frontier or as gas-oil to enrich the gas of the city, this use of a petroleum product is not increasing on the same scale as the industrial uses. In power generation oil takes on much larger economic values, whether as gasoline or as fuel oil. The demand for gasoline seems to obey no law of normal increase, and the higher cost of coal in recent years has greatly stimulated the use of fuel oil under steam boilers. Fortunately the rapid increase in the consumption of fuel oil by locomotives seems to have been checked at about the same time that it has found a wider use in stationary steam plants. Last year the public utility power plants of the United States consumed 11,000,000 barrels of fuel oil in generating electricity, nearly half of it in coal-less California. In the East the present oil shortage has doubtless started a reaction in the popularity of fuel oil caused by the coal shortage in the war years. The more adequate and reliable supply of coal must, in the long run, give coal the advantage for use under stationary boilers, for despite the labor economy attained through use of oil the assurance of an unfailing supply of fuel is of first importance in industry.

Prices also will eventually exert an automatic control on the use of oil products. Not only is the inadequate supply stimulating high-cost production as well as rewarding low-cost operation with unusual profits, but however much we may desire low-priced gasoline we can not wave aside the economic facts of supply and demand. High prices are here for crude oil and for every one of its products, and high prices will help to bring about a kind of economic survival. The more essential use of oil—that is, the use of oil where it serves the greatest end—will survive, and business practice, public opinion, and even, if needed, governmental regulation, should work together to enforce obedience to this democratic rule of the greatest good to the greatest number. Plenty and cheapness have led to waste; scarcity and dearth ought to promote thrift. It is a problem for the nation as well as for your individual plant to get larger values out of the higher-cost coal and oil.

In any weighing of the uses of petroleum, certain changes in practice appear inevitable. The use of gasoline to serve our pleasure cannot go on unchecked—the joy ride is not the kind of "pursuit of happiness" regarded as an "unalienable right" by our Revolu-

tionary fathers. The use of fuel oil as a substitute for coal must be discouraged, for our Navy and our merchant marine need the fluid fuel for reasons that do not apply to stationary boilers or even steam locomotives. On terra firma a power program can be worked out that will hitch up coal mine and water fall efficiently, and both industry and transportation can be fully electrified to the end that except perhaps on the Pacific Coast, not a barrel of oil should be used under boilers. The necessity of caution in enlarging the field of fuel oil is the more apparent when we realize that, as suggested by the Bureau of Mines, every increase in demand for other petroleum products for a higher use entails a loss in the percentage of fuel oil produced.

The requirements of the American Navy and the new merchant marine present a priority demand of the first order. Admiral Griffin, the chief of the bureau of steam engineering of the United States Navy, informs me that the oil-burning vessels ready for service aggregate more than 6,000,000 hp and that other vessels under construction will bring this total up to nearly 9,000,000 hp. The Navy now needs 8,000,000 barrels of fuel oil a year, yet this figure is small compared with the requirements of the Shipping Board, which are stated by Paul Foley, its director of operations, as 40,000,000 barrels for 1920 and 60,000,000 for 1921. If the American Flag is to fly on the seven seas the motive power to carry it must be assured, and here is one demand for fuel oil which alone equals the present output of our refineries for about four months. Surely no American with vision wishes to contemplate even the possibility of a shortage of fuel oil that would endanger the immediate availability of these battleships, cruisers, and destroyers or interfere with the successful operation of the passenger and freight steamers in the construction of which our nation has invested so many millions.

In our attention to the generation of power to meet the needs of industry and transportation, we give too little thought to one unique function of oil—that of saving power. Machinery without lubrication is unthinkable; adequate lubrication saves energy and makes it available for use as well as adds to the life of the machine. There is little danger of shortage in lubricating oil for our Navy, for the daily refinery output, as reported by the Bureau of Mines, is almost sufficient to supply the Navy for a year with lubricating oil, whereas about three weeks' run would be necessary to meet the Navy's annual needs in fuel oil. Yet, on second thought, we realize how universal is the use of lubricating oil, in the home as well as in the largest steel plant, in the motorcycle and locomotive, in the electric fan and the power station—everywhere oil is needed in the bearings, a single drop or many gallons. And in looking to industry's future needs of this petroleum product large plans should be made, for our use of power and machinery is increasing faster than is generally appreciated. The statistics of electric power generation collected monthly by the Geological Survey show that the war-peak was exceeded last year, and already the opening months of 1920 are ahead of the corresponding months of 1919 by 14 per cent; and an increase on this scale means not only larger fuel consumption but a larger requirement of lubricating oil. Even more significant in its suggestion of future needs is a recent order for 1,000,000 small motors for household use. The introduc-

tion of labor-saving machines at this rate will make lubricating oil a necessity in every home.

This need for oil to insure our industrial life inspires the call for pioneering on other continents by American oil companies. In the world estimates we credit South America with a third more oil reserves than the United States, so that one guidepost for the explorer and developer plainly points to the south. To the steel industry, this American hunt for oil, not only in the Western Hemisphere but in the Far East, has special significance. Wherever an oil field is developed by American capital not only will its product be available either for our home refineries or for the more distant American bunker stations at the world's cross-roads, but all the supplies needed to develop and operate this foreign oil field will come from the United States. An "International Oil" operating in South America means another market for the product of a "National Tube" operating in Pennsylvania.

To you leaders in a great industry is given the privilege of planning for the future on a large scale. Perhaps we Americans, as possessors of a continent-wide country with unparalleled wealth of resources, have thought more of exports than of imports—more of markets for our products than of raw materials for our industry. Yet commerce means exchange of commodities, and for the future supply of some things that we need we must look beyond our own shores. And our industrial program for the future is well worth safeguarding, for upon it depends our national welfare.

That industry is not an end unto itself was well illustrated by a photograph in this spring's Pittsburgh exhibition. The picture had the simple title, "The Day's Work." In the foreground was a family wash, hung out on the fence; beyond loomed the high stack of a blast furnace. This commonplace scene well portrays the two types of industry—the one, that of the humble home-maker; the other, that of progressive big business—and in our planning for industrial development our cue should be to keep the American home ever in the foreground. It is this kind of vision, this regard for the future, that arouses us to activity in protecting America's supply of every essential material.

Editor's Note—An article of particular interest on the subject of fuel oil is to be found in the April issue of THE BLAST FURNACE AND STEEL PLANT, under the subject, "Heating Furnaces and Annealing Furnaces." This article, written by W. Trinks, covers the advantages and disadvantages of oil as a furnace fuel thoroughly, by treating of its heat value, its specific gravity and its viscosity. Mention is also made of the various type burners used in inducing the oil in the furnaces. The following interesting paragraph is quoted from Professor Trinks' article:

"Fuel oil has many advantages. It can readily be stored above or below ground, and in out-of-the-way places. In that respect it not only shares the convenience of coal as fuel, but goes far ahead of it. Fuel oil is always ready to serve, just like natural gas or city gas. But it is even more ready to serve, because natural gas is frequently shut off in cold weather. There are no standby losses with oil such as are inevitable with gas producers, water gas plants, or any other equipment for the generation of an industrial gas."

Fatigue of Metals Under Repeated Stresses

Importance of Resistance to Repeated Stresses—Fatigue Phenomena—Testing Machines—The S-N Curve—Treatments Affecting Fatigue Strength—Localized Stress and Its Importance.

By H. F. MOORE* and J. B. KOMMERS.†

THE STRENGTH of materials is commonly determined by tests under a load gradually increasing from zero to the ultimate of the test specimen. In nearly all computations of stress and strain the basis of the computation is the action produced by a steady load applied but once. For more than half a century it has been recognized that under loads repeated many thousands of times the behavior of material might be quite different from the behavior under a single application of load. The growing use of high-speed machinery has been especially influential in necessitating the consideration of the strength of material under repeated stress.

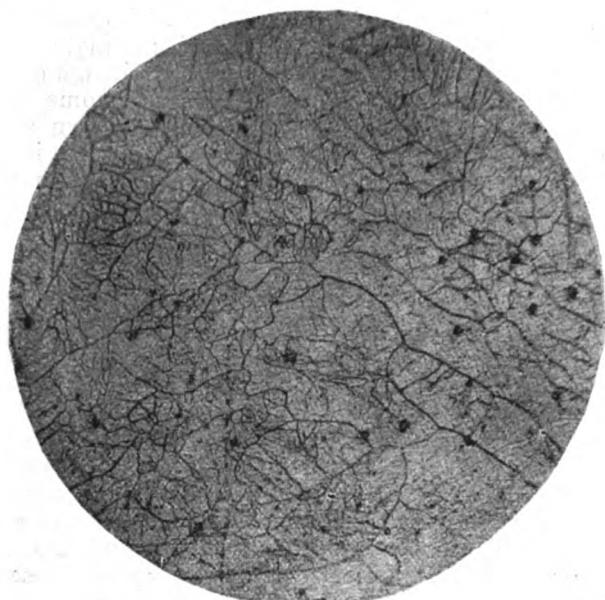


Fig. 1a.

In a general way the difference in the behavior of material under repeated loads and under a single load (or a load applied but a few times) is shown by the tendency toward gradual breakdown of the material under repeated load. Under a single application of load the material of a structure either withstands the load or it fails; under load repeated many thousands of times the material may withstand the load for awhile, and then fail by the gradual spread of cracks or other local injuries to the material. Under repeated load strains which would be of no importance if but one loading were to be applied may form a nucleus for damage which gradually spreads until the whole member fails.

The failure of machine parts under repeated stress

Paper read before seventeenth general meeting of the American Iron and Steel Institute.

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has come to be commonly spoken of as due to "fatigue" of the material. The cause of such failure used to be thought to be the "crystallization" of the metal, but, as will be noted later, the phenomenon is one of a breaking up of crystals rather than of their formation. The development of the internal combustion engine, the steam turbine, the automobile, and the airplane have made this problem of fatigue of materials of increasingly marked moment during recent years. The accompanying table gives some idea of the number of repetitions of stress in the normal "lifetime" of various structural and machine members:

Part of structure of machine	Approximate number of repetitions of stress in the "lifetime" of the structure or machine
Railroad bridge, chord members	2,000,000
Elevated railroad structure, floor beams ...	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, car wheel loads	15,000,000
Airplane engine crankshaft	18,000,000
Car axles	50,000,000
Automobile engine crankshaft	120,000,000
Line-shafting in shops	360,000,000
Steam engine, piston rods, connecting rods and crankshafts	1,000,000,000
Steam-turbine shafts, bending stresses	15,000,000,000
Steam-turbine blades	250,000,000,000

Fatigue Phenomena.

The first study of fatigue phenomena on a large scale was made in Germany by Wohler, who published his results in 1870. These results may be summarized as follows:

1. Repeated application of stress to a structural member will finally cause failure not only when the unit stress is less than the static ultimate strength of the material, but even when it is less than the static elastic limit as ordinarily determined.
2. Within certain limits the range of stress (difference between maximum and minimum stress) rather than the maximum unit stress, determines the number of cycles before rupture.
3. As the maximum unit stress is increased, the range must be decreased in order not to shorten the life of the member.
4. For the same life in the case of complete reversal of a unit stress, the stress should be only one-half or two-thirds of the maximum stress if the variation is from zero to a maximum.

A fatigue failure is characterized by the complete absence of elongation or reduction of area at the break. The fracture is sudden and is similar to that which is ordinarily expected only from brittle materials. A rotating beam will crack at right angles to the length of the beam, which is also at right angles to the direction of stress.

Metals, while being subjected to fatigue, have been observed under the microscope, and it has been found that the crystals of which a metal is composed will allow deformation to occur by movement along

certain gliding planes within the crystal. This gliding or slipping is indicated by the appearance of lines running across the crystals, as shown in Fig. 1. These lines are called "slip lines," or "slip bands." Careful examination of cross-sections cut at right angles to the surfaces on which the slip lines occur has shown that the slipping causes microscopic ridges, and depressions of the surface, in the nature of steps. Vertical illumination of such a surface shows the steps as bright surfaces, and the inclined surfaces between the steps as dark lines or bands. As the test of the material in fatigue is continued the slip lines become more numerous, and also broaden. Finally some of these bands develop into a crack which spreads to other crystals and thus causes failure. It has been found that the crystals which first develop slip lines are not necessarily the ones in which final failure occurs.

In general, fatigue failure follows a path through the crystal grains themselves rather than along their boundaries, and this is true even though in going from one crystal to another the plane of failure must change its direction, because of the different orientation of the crystals.

It appears, therefore, that the primary cause of fatigue failure is localized deformation. This deformation in any particular crystal is very small in amount and apparently even very accurate and sensitive extensometers cannot detect the deterioration which is going on.

Because steel is made up of many minute crystals, the structure is not likely to be homogeneous. Furthermore, there are likely to be many microscopic flaws throughout the material. Somewhere, due either to non-homogeneity or to flaws, there will be high local stresses, and at such places the material will be most likely to deteriorate by the repeated action of fatigue stresses. The presence of internal stresses, due to previous heat-treatment or mechanical treatment, would also tend to weaken the material when fatigue stresses of a similar kind are applied later.

Tests conducted with apparatus of extreme sensitivity have shown that the action of materials within the ordinary elastic limit is not perfectly elastic. For instance, when a specimen is first loaded in tension, and then the load is reduced to zero, the return path of the stress-deformation curve does not coincide with the original path, but lies slightly lower, the deformation seeming to lag behind the stress, so that when the stress is zero the deformation of the specimen is not yet back at zero. If now the specimen is loaded in compression, and the load reduced to zero, it is found that a loop has been formed by the stress-deformation curve. This loop is called a mechanical hysteresis loop, from analogy with magnetic hysteresis.

The area of this loop represents energy which has been absorbed by the specimen, but which has not been given back again. In each cycle of stress, therefore, there is a small amount of work done because of the inelastic action of the material.

In careful torsion tests† Guest and Lea obtained hysteresis loops for mild steel at unit stresses which were very much below what would ordinarily be called the elastic limit. Such results constitute a further explanation of the possibility of failure of a material when stressed within what has heretofore been looked upon as the elastic limit. This so-called elastic limit may be regarded as of value when dis-

cussing static stresses, but it seems evident that it is not an elastic limit for reversed stresses, because the hysteresis loops indicate inelastic action.

Baird* has shown that when cyclical stress sufficiently below the elastic limit is applied to a specimen there is no hysteresis loop formed at first, the amount of damage done during each cycle of stress being apparently too small to be indicated even by a very delicate extensometer. However, after quite a few thousands of repetitions of stress the cumulative effect of the repetitions is evidently of such a nature as to make measurable the changes which occur in the specimen, and a hysteresis loop appears.

Testing Machines.

In determining the resistance of metals to fatigue, Wohler used machines which subjected the specimens to direct tension and compression, to repeated bend-

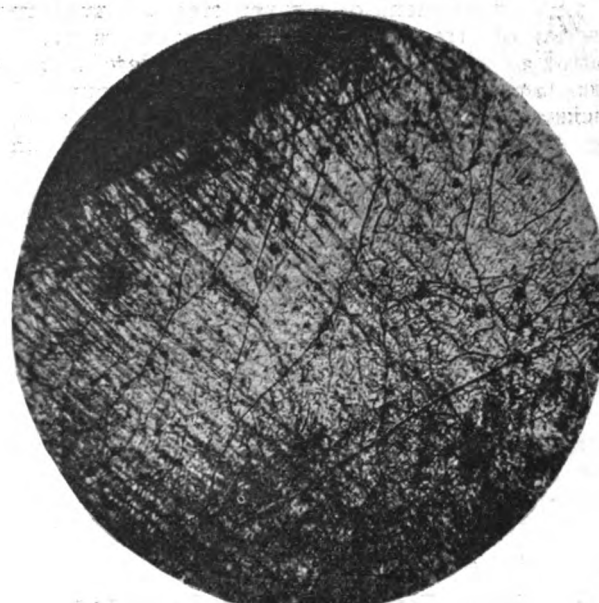


Fig. 1b.

ing on a stationary beam, to reversed bending on a rotating cantilever beam, to repeated torsion, and to reversed torsion. In the direct stress, repeated bending, and in the torsion tests Wohler used machines in which calibrated springs were employed to measure the load applied to the specimen. This general type of machine is quite common and is illustrated in Fig. 2. The rotating beam type, either cantilever or simple beam, has probably been more extensively used than any other machine. This type is illustrated in Fig. 3.

Wohler's machines applied the stresses at rates less than 100 per minute so that many weeks of testing were required to stress a specimen as many as 10,000,000 times. In later types of machines attempts have been made to increase the speed of the machines, and speeds up to 2,000 revolutions per minute have been used successfully. A machine of this kind running 24 hours per day will give results fairly rapidly.

Various other types of testing machines have been employed by experimenters. In some the stress is produced in the specimen by the acceleration effects of reciprocating masses, in others the pull is applied by an electro magnet, and in still others the reversed

†Proc. Royal Society, 1916-17. Vol. 93.

*Phil. Trans. Royal Society, 1910. Vol. A, 210, p. 35.

bending which is produced occurs in only one plane.

Machines for producing reversed bending on a cantilever beam have been used by Arnold and others. These machines stress the materials beyond their yield points so as to produce failure after only a few hundreds or thousands of cycles of stress. In such a test the stress to which a specimen is subjected is not known, and it is therefore difficult to interpret the results of the test. Thus far it has not been shown what relation exists between this short-time test and the test which stresses materials only within their elastic limits.

In the ordinary fatigue test the machine is set to produce a certain stress in the specimen, and the test is continued until failure occurs; the number of cycles of stress before failure being recorded by a suitable counter.

The S-N Curve.

When specimens of a given steel are subjected to a series of stresses the results may be conveniently plotted as a curve having the unit stress, S , as ordinates, and the number of cycles for rupture, N , as abscissae. This curve may be plotted as shown in Fig. 4a, or by plotting the logarithms of S and N

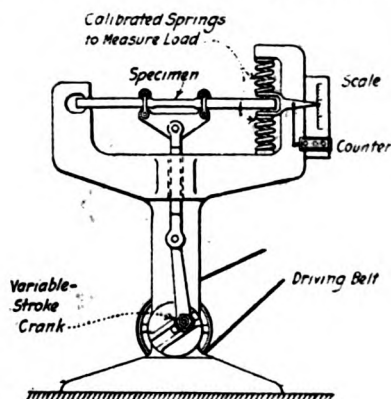


Fig. 2—Testing machine for fatigue tests, using calibrated springs to measure load.

curves such as shown in Fig. 4b are obtained. Basquin† has pointed out that these logarithmic curves are very well represented by a straight line, at least up to about 1,000,000 cycles.

In discussions of fatigue tests the term "endurance limit" has been employed. By this is meant the unit stress at which the S - N curves as in Fig. 4a seem to become horizontal, and therefore, presumably, the unit stress which the material could endure indefinitely. It has often been assumed that the unit stress corresponding to 1,000,000 cycles is too high to be considered as an endurance limit, and that failures may be obtained at lower stresses if the tests are continued a sufficient length of time. This matter is related to another doubtful point in connection with the curves of Fig. 4b. The doubt arises because it is not known whether the logarithmic curves continue as straight lines for large value of N . It is of the greatest importance to know the nature of the S - N curve for large value of N , and this would probably be determined with sufficient exactness if tests were continued up to 100,000,000 cycles. If there is an endurance limit such tests will probably determine it with a sufficient degree of accuracy.

†Proc. Amer. Soc. for Test. Mat. 1915. Vol. 15, part 11, p. 938.

It is evident from Fig. 4b that any formula for fatigue stress which is based on the assumption that the S - N curve is a straight line on logarithmic paper

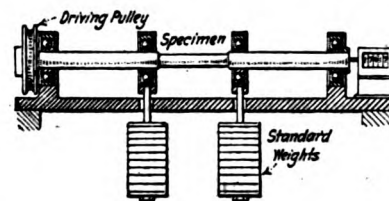


Fig. 3a.

will give results on the side of safety, because for increasing values of N the corresponding values of S become smaller and smaller. In the present state of knowledge regarding fatigue, such formulas as proposed by Moore and Seely‡, and the factors of safety proposed by Koppers* in connection with J. B. Johnson's repeated stress formula, may be considered as satisfactory for use in design, for in both cases the assumption is made that the S - N curve is a straight line on logarithmic paper.

It should be noted that the use of an "endurance limit" assumes that this stress may be applied an indefinite number of times without causing rupture of the material. The relation expressed in Fig. 4b,

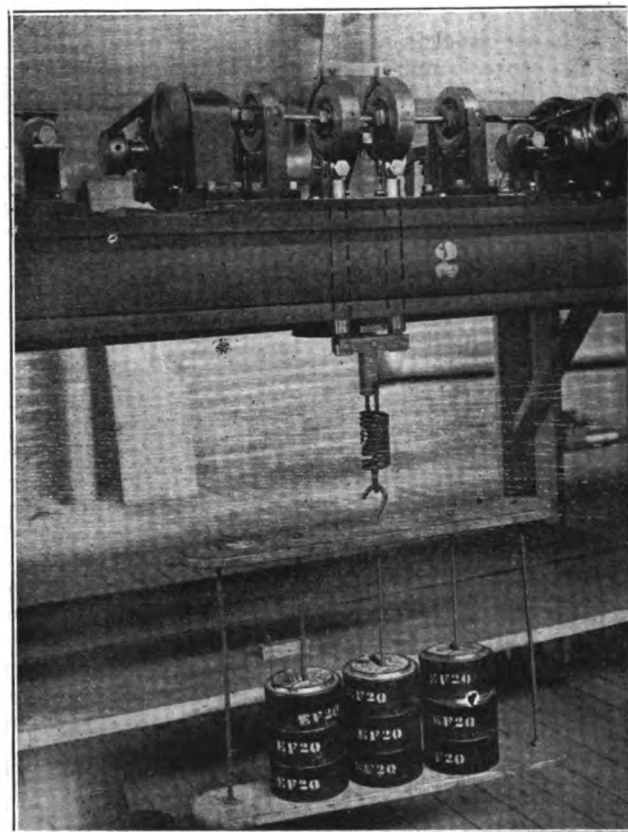


Fig. 3b—Photograph of machine used in present joint investigation of fatigue of metals.

called the exponential hypothesis, assumes that any stress, however small, if applied often enough, will finally cause failure.

‡Proc. Amer. Soc. for Test. Mat. 1915. Vol. 15, part 11, p. 938.

*Engineering News-Record. Nov. 27, Dec. 4, 1919.

Criteria for Fatigue Strength.

Attempts have been made to show that a relation exists between the endurance limit and the elastic limit as determined from a static tensile test. These attempts have not been satisfactory, and this is to be expected, since the endurance limit which was used was itself indefinite. Furthermore, the elastic limit is also an indefinite quantity, and depends to a considerable extent upon the sensitiveness and accuracy of the instruments employed in determining it and upon the accuracy used in plotting the results. It has been shown that a material having a higher elastic limit than another one is not necessarily better in withstanding repeated stresses. It has also been shown that logarithmic S-N curves for two such materials sometimes cross each other, so that the material which is apparently the better one for high stresses and low values of N is the poorer one for low stresses and high values of N . Data for low stresses and higher values of N are the ones that are of greatest importance to the designer of structures. The whole question of the relation of fatigue results and results from static tests can be more satisfactorily discussed when information is available for tests up to 100,000,000 cycles.

Bauschinger, in his fatigue experiments, showed another reason why the ordinary elastic limit is misleading as a criterion of fatigue strength. He found that the elastic limits in tension and compression as ordinarily determined depend very largely upon the stresses to which the material has been subjected in fabrication. He called the elastic limits so determined the primitive elastic limits. He showed that when a specimen is subjected to equal alternating stresses of tension and compression which are gradually increased, that there are set up two new elastic limits, which are equal, and which may be widely different from the "primitive" elastic limits. He called these new elastic limits the "natural" elastic limits, and the range between them the "natural" range. He showed further that if the elastic limit in tension is now raised, the elastic limit in compression will be decreased by a definite but not necessarily the same amount. He found that a specimen stressed within this "natural" range will withstand several millions of repetitions of stress without failure, and he proposed this "natural" range as a criterion of fatigue strength.

The comparison of fatigue properties by means of a short-time test in which stresses beyond the yield

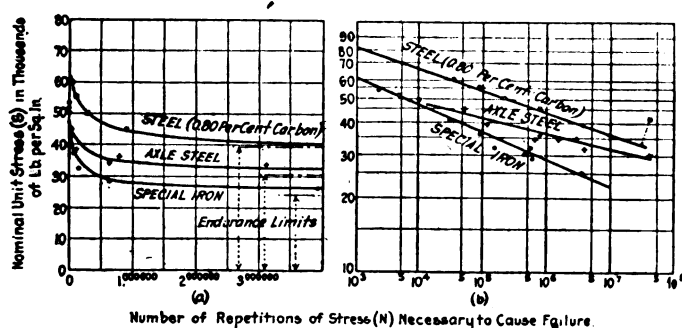


Fig. 4—Diagram of results of fatigue tests (S-N diagrams)
a—diagram with ordinary coordinates.
b—diagram with logarithmic coordinates.

point are employed, has already been mentioned.

The proposal has been made to compare the fa-

tigue properties by means of the number of cycles of stress that is withstood for a constant standard stress. Also it has been proposed to determine the fatigue strength by determining the stress which causes failure for a standard value of N . These methods would determine only one point on the S-N curve, and since these curves sometimes cross each other the information would not be reliable unless tests were carried out to a very large value of N .

To compare fatigue properties by determining the S-N curves up to N equals 1,000,000 cycles, is likely to be misleading for the same reason as mentioned in the preceding paragraph.

Prof. J. H. Smith† has proposed a method of determining the fatigue range by determining the first yield of the specimen under cyclical stress by means of a very sensitive extensometer. Long-time fatigue tests are lacking to prove that this elastic range is the range which the material could withstand indefinitely.

W. J. Francke, of New Brunswick, N. J., has recently developed a very delicate flexure testing machine which gives some promise of detecting the failure of material over very small areas, and hence, may possibly give some information as to the fatigue-resisting properties of the material being tested.

C. E. Stromeyer‡ has also suggested a short-time test for determining fatigue strength. He subjected the material to alternating torsion and determined the unit stress at which perceptible heating of the specimen occurred. Here, again, long-time fatigue tests are lacking to prove that the method is reliable.

Other short-time tests which have been proposed are dying out of vibrations in a "tuning fork" specimen, tests of magnetic permeability detection of the appearance of slip lines, and impact tests.

There is at present no short-time test which has been proved to be a reliable criterion of fatigue strength. If such a test could be developed it would of course be of the greatest commercial importance.

Treatments Affecting Fatigue Strength.

The effect of various heat-treatments on fatigue strength has not been studied systematically, although it is known that such treatments have an important influence. Overheating, which tends to make material brittle, seems always greatly to decrease the fatigue strength. Such overheated material may often be restored by proper reheating. Annealing, in general seems to reduce the fatigue strength somewhat. The results on overstrained material are somewhat contradictory, some tests seeming to indicate increased fatigue strength, and others that tensile overstrain decreases fatigue strength while compressive overstrain increases the strength. The sorbitic structure in steels seems to be most effective in resisting fatigue, while the martensitic structure is weak. Material which has been subjected to repeated stresses apparently does not have its life increased by annealing or by rest.

In normal carbon steels the fatigue strength seems to increase with increase of carbon up to about 0.9 per cent carbon. The effect of nickel, chromium, vanadium, etc., upon fatigue properties has not been studied systematically, although apparently these alloys improve the material.

Localized Stress and Its Importance.

One outstanding feature of fatigue phenomena in metals is the importance of small localized stresses.

†Journ. Iron and Steel Inst. 1910. Vol. 82, p. 296.

‡Proc. Royal Society, 1914. Vol. A, 90, p. 411.

Because their derivation depends on mathematical processes it is easy to come to regard the ordinary formulas for computing stresses in machine and structural parts as exact; but, as a matter of fact, such formulas give results representing general conditions of stress, and neglect the existence of hundreds of localized stresses affecting minute areas. For example, the ordinary method of computing stress in a plate under tension, punched for rivet holes, is to divide the load on a strip of the plate by the net width of the strip after the width of rivet holes has been deducted; this method assumes that the tension is uniformly distributed across the plate, and neglects to consider concentration of stress near the edges of the holes where the intensity of stress may be twice as high as the computed stress. Shoulders with sharp fillets, screw threads and shafts with keyways are a few of the many illustrations which might be given of members in which the application of the ordinary methods of stress computation neglect localized stresses.

So long as a member is subjected to static load, or if the load on it is repeated only a few hundred times in its life these localized stresses do no particular harm; the area affected is very small, the general deformation of the member is not appreciably influenced, and the load-carrying burden is shifted from the minute overstressed areas to the large normally stressed areas with no appreciable increase in the distress of the member. Under a loading repeated thousands of times this is all changed. The minute overstressed areas form centers of damage which spreads in the form of microscopic cracks, and at the end of each crack there is a region of high localized stress which caused the spread of damage to continue, often to continue until the minute damaged area grows into a large damaged area, and failure follows. The growth of these microscopic cracks is shown in Fig. 1.

This spreading of structural damage in the form of microscopic cracks explains the suddenness of failure under fatigue. A flat bar of soft steel may be bent double without cracking, but if it be cut half across by a fine saw cut and then bent it snaps at the saw cut. The microscopic cracks through metal under repeated stress are equivalent to little saw cuts, which gradually join each other; they have very little effect on the general deflection of the metal, but gradually develop localized planes of weakness, along which sudden failure may occur.

The phenomena of localized stress also helps to explain why the "elastic limit" as determined by a testing machine test is not a sure index of resistance to fatigue under repeated stress. Suppose the metal to be tested is of such chemical composition and has received such heat-treatment that it is, in general, strong, but due to the method of production or treatment during fabrication it contains blowholes, "snow-flakes," minute cracks, or initial strains. Then if its elastic limit is determined by a gradually increasing load these minute flaws will show very little effect, because they affect only a minute portion of the part stressed by the testing machine, while the extensometer measures the stretch over a considerable volume of metal. If the yield point is determined by the "drop of the beam" the yielding at a microscopic flaw will not cause anywhere nearly enough change of load to make the beam drop.

If, however, the metal is put into service under repeated stress each blowhole, "snowflake" or crack is

a potential center of high localized stress and a potential nucleus of progressively spreading damage which may result in sudden fatigue failure.

Localized stress may be external as well as internal. It may be caused by internal flaws as outlined above or at external irregularities of surface. If any structural or machine member has in its outline a sharp inwardly-projecting corner it can be shown that the stress at that corner is theoretically infinite, and that the localized stress at any fillet increases very rapidly as the radius of the fillet is reduced. Rough turned finish may easily leave a member, e. g., a car axle, with a series of grooves of small radius at the root of which grooves occur very high localized stresses. In this connection it is of interest to note that the British experimenters, Eden, Rose, and Cunningham, showed that the endurance under repeated stress of a polished specimen could be materially reduced by a needle scratch on its surface. It is, of course, impossible that all machine parts subjected to repeated stress should have a high polish all over, or that they should keep such a polish if it were applied in the beginning; it is, however, possible that such parts be given generous fillets at shoulders, and that care be taken to make the surface finish the best practicable. In the present state of knowledge material which under the microscope shows flaws, or cracks, or, which tested with the strain gage shows high initial stress, should be viewed with suspicion, even if in the testing machine it shows a high "elastic limit."

Outline of Investigation of Fatigue of Metals.

In the fall of 1919, there was started at the University of Illinois, an Investigation of the Fatigue of Metals under the joint auspices of the National Research Council, Engineering Foundation, and Illinois Engineering Experiment Station. This investigation is at present organized and financed to be carried on until the fall of 1921. In planning this investigation it was decided by the advisory committee of the National Research Council that it should be the object of the investigation to make a series of fatigue tests of seven or eight typical steels accompanied by very careful static tests, and impact tests, and in connection with these tests various special tests including magnetic tests.

The testing machine chosen for the repeated stress tests is of the rotating beam type, and is practically the same as that described by F. M. Farmer before the American Society for Testing Materials, in June, 1919. This type gives reversals of a very definitely known bending moment, and there is a considerable portion of the specimen under constant bending moment. The specimen is a straight rod slightly reduced in section over the middle portion of its length. Fig. 36 shows the testing machine and the specimen.

By past investigators there has been obtained a considerable amount of data on the fatigue failure of metals, but the committee felt that there was need for a comprehensive series of tests on metal whose history was thoroughly known, correlated with very careful static tests of the same material. It is planned for each kind of steel tested, and for each heat-treatment given each kind of steel to run not less than six tests to 100,000,000 repetitions of stress, and to obtain 18 to 24 points on a diagram of fiber stress plotted against numbers of repetitions of stress necessary to cause failure.

The Use of the Microscope and the Heat Treatment of Steel

The Microscopic Study of Steel Has Made Possible Improvements and Refinements in the Heat-Treatment of That Metal Which Could Not Have Been Accomplished Without Its Aid.

By ALBERT SAUVEUR,

Professor of Metallurgy, Harvard University.

IT IS NOT without hesitation that I accepted the kind invitation extended to me to contribute a paper on "The Value of the Microscope in Metallurgy," because of the difficulty of doing justice to the subject in the necessarily small compass afforded by our transactions and because of lack of time for the careful preparation such paper calls for. Of necessity I must leave out of consideration the important and growing use of the microscope in non-ferrous metallurgy, to confine my remarks to iron and steel. But even to cover this subject alone would require the writing of a treatise. I must, therefore, select such phase of it as is most likely to be of interest to the members of this institute. With this in view, I shall consider chiefly the services rendered by the microscope in the heat-treatment of steel.

Referring in a general way to the importance of metallography I venture to quote here some remarks formulated in 1912:

"It is not to be supposed that the path trodden during the last score of years was at all times smooth and free from obstacles. Indeed, the truth of the proverb that there is no royal road to knowledge was constantly and forcibly impressed on the mind of those engaged in the arduous task of lifting metallography to a higher level.

"Its short history resembles the history of the development of all sciences. At the outset a mist so thick surrounds the goal that only the most courageous and better equipped attempt to pierce it and perchance they may be rewarded by a gleam of light. This gives courage to others and the new recruits add strength to the besieging party. Then follows the well-known attacking methods of scientific tactics and strategy, and after many defeats and now and then a victorious battle the goal is in sight, but only in sight and never to be actually reached, for in our way stands the great universal mystery of nature: what is matter? What is life?

"Nevertheless there is reward enough for the scientist in the feeling that he has approached the goal, that he has secured a better point of vantage from which to contemplate it. The game was worth candle. And if scientific workers must necessarily fail in their efforts to arrive at the true definition of matter, whatever be the field of their labor, they at least learn a great deal concerning the ways of matter, and it is with the ways of matter that the material world is chiefly concerned. Hence the usefulness of scientific investigation, hence the usefulness of metallography.

Paper read before the seventeenth general meeting of the American Iron and Steel Institute.

"Like any other science with any claim to commercial recognition, metallography has had first to withstand the attack and later to overcome the ill-will and reluctance of the so-called 'practical man' with a decided contempt for anything scientific. He represents the industrial philistine clumsily standing in the way of scientific applications to industrial operations. Fortunately, while his interference may retard progress it cannot prevent it. Had he had his own way, neither the testing machine, nor the chemical laboratory, nor the metallographical laboratory, nor the pyrometer would ever have been introduced in iron and steel works."

Speaking in 1904 of the practical value of metallography in iron and steel making, the author wrote the following, which it may not be out of place to reproduce here:

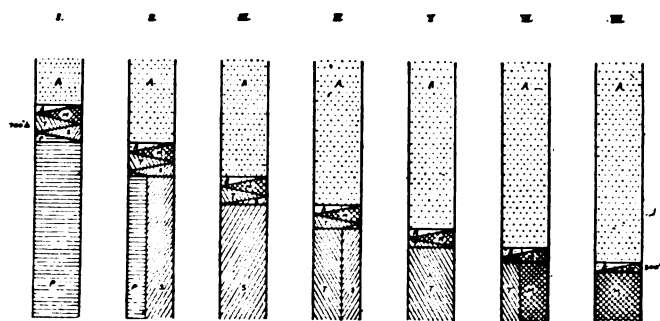


Fig. 1.

"History, however, must repeat itself, and the evolution of the metallographist bids fair to be an exact duplicate of the evolution of the iron chemist; the same landmarks indicate his course; distrust, reluctant acceptance, unreasonable and foolish expectations from his work, disappointment because these expectations were not fulfilled and finally the finding of his proper sphere and recognition of his worth."

Replying, in 1913, to some foolish criticism, I wrote:

"If most of us must of necessity follow the beaten path, let us at least do so without intellectual blinders, that our vision may be broader, that we may contemplate those—shall I say, more fortunate ones—who have been able or have been permitted to depart from it; and let us do so with reverence, for some of them at least are building roads that will lead nearer and over smoother ground toward the desired end. Surely these road builders are entitled to the respect and encouragement of all pilgrims bound toward a common goal, for their roads, when open to traffic, will be the highways of travel."

These roads are now open to traffic and they have become the highways of travel, even though foolishly or destructively minded persons may still be at the

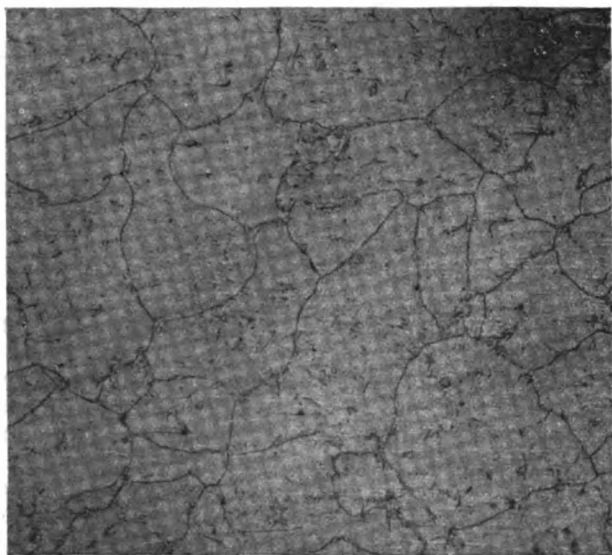


Fig. 2.

gate throwing harmless pebbles at the passers-by.

In no department of metallurgy has the microscope rendered greater services than in the heat-treatment of steel.

It may be contended at the outset that no satisfactory explanation can be given of the heat-treatment of steel without having recourse to the microscope. Metallography alone supplies it and a knowledge of its teaching is indispensable to the intelligent conduct of the needed manipulations; indispensable also to further progress in the art of treating steel.

It would be difficult to find a contribution written within the last 10 years in any of our technical transactions on the subject of the heat-treatment of steel which is not based in part and often chiefly, if

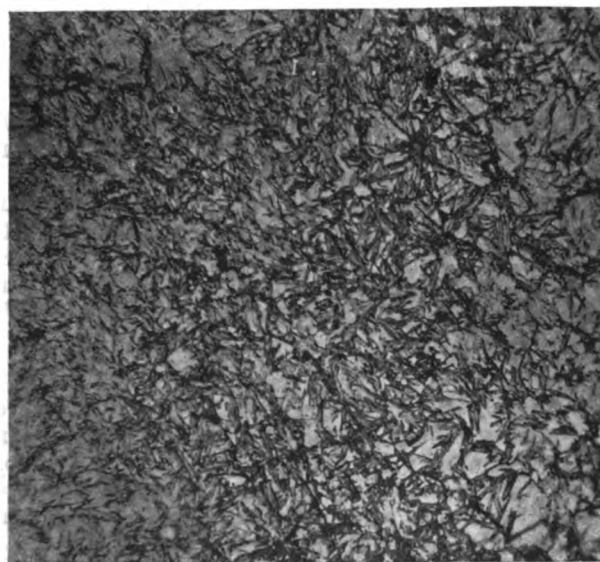


Fig. 3.

not wholly, on the teaching of the microscope. The reason for this is obvious. If the heat-treatment of steel is of such vastly greater importance and sig-

nificance than the heat-treatment of any other metal or alloy, if it implies a vastly greater number of possible treatments and of possible results, it is because steel, unlike other metals and alloys, undergoes on cooling (and, on heating) considerably below its melting point, momentous transformations which it is possible, at will, to arrest at any desired stage, thereby conferring to the metal an almost infinite number of combinations of physical properties to meet our requirements. Were it not for the microscope we would be in almost complete darkness as to the nature of these transformations and as to the extent to which a given treatment has permitted them to proceed.

The diagram, Fig. 1, may help in visualizing these transformations as well as the results obtained by various heat treatments. For the sake of simplicity, the steel considered is assumed to be of eutectoid composition, that is, to contain in the vicinity of 0.85 per cent carbon and free therefore from excess ferrite or cementite. It is well known that when such a steel is allowed to cool slowly it exhibits a marked thermal critical point at about 700 degrees C, result-



Fig. 4.

ing from a spontaneous evolution of heat at that temperature, and it is also well known that on cooling through its critical point this steel which at higher temperature consisted of a solid solution of carbon in iron (austenite) is now converted into an aggregate of iron (ferrite) and the carbide of iron Fe_3C (cementite) the resulting intimate mechanical mixture of these two components being called "pearlite."

Austenite, however, is not abruptly converted into pearlite on reaching its critical point. The transformation is gradual, three stages at least being recognized as marking as many steps in the transformation. These stages correspond to readily distinguishable structures. They are often referred to as "transition constituents," and are called respectively, "martensite," "troostite" and "sorbite." This gradual transformation of austenite into pearlite is depicted in Fig. 1. If the cooling be sufficiently slow, the transformation is complete and the steel becomes pearlitic, a condition which imparts to it maximum softness and ductility and minimum tenacity.

By hastening and regulating the rate of cooling it is possible to prevent the full transformation at any desired stage in accordance with the set of physical properties desired. This partial suppression of the transformation is made possible by the lowering of the critical point, that is, of the temperature at which the transformation takes place.

In other words the faster the cooling the lower the temperature of transformation, and the lower that temperature the more incomplete the transformation. If by the very rapid cooling involved in quenching steel the critical temperature remained at 700 degrees C, the steel would become pearlitic, and the hardening of steel therefore would not be possible. Quenching steel for hardening, however, lowers the transformation temperature to about 300 degrees C, and at that low temperature it is possible for austenite to be converted into martensite only. The transformation is then arrested, the steel remains martensitic, and hence becomes intensely hard. It has been attempted to indicate in Fig 1, (1) the influence of the rate of cooling on the position of the temperature of transformation, and (2) the influence of the position of the temperature of transformation on the amount of transformation taking place. The critical point has been represented in each case by a set of two parallel, horizontal lines in order to make it possible to indicate the progress of the transformation as the metal cools through this point. Seven rates of cooling are depicted yielding, respectively, pearlite, pearlito-sorbite, sorbite, sorbito-troostite, troostite, troostito-martensite, and martensite. Typical illustrations of

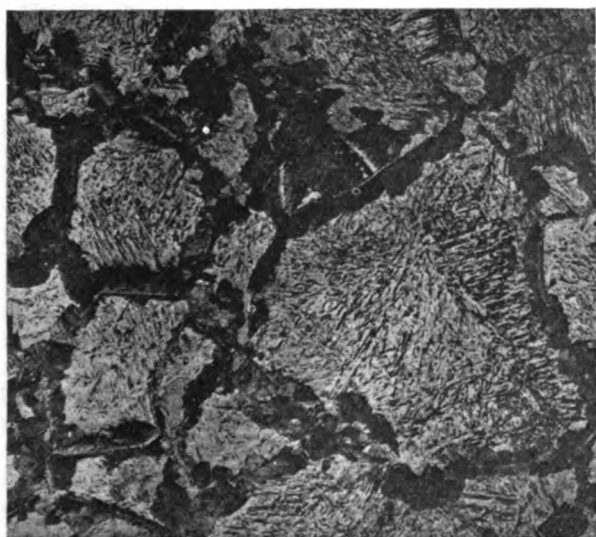


Fig. 5.

these constituents are appended to this paper. It is well known that it is not possible to prevent altogether the transformation of carbon steel, that is, to retain it in its austenitic condition, the fastest rate of cooling producing martensite.

From the teaching of the diagram of Fig. 1, we naturally infer that in order to produce pearlito-sorbite steel the metal should be cooled at such a rate as to lower its critical point to about 625 degrees C, while to obtain sorbitic, sorbito-troostitic, troostitic, troosto-martensitic or martensitic steel, the cooling of the metal should be conducted with increasing rapidity.

It should be born in mind, however, that while it is known that when the transformation takes place at 700 degrees C the steel becomes pearlitic, whereas with its transformation lowered to 300 degrees C it becomes martensitic, it is not claimed that the temperature of transformation corresponding to the various structures described are accurately indicated in

the diagram and that for obvious reasons the aim is to depict the mechanism of the critical transformation of steel and the relation existing between the

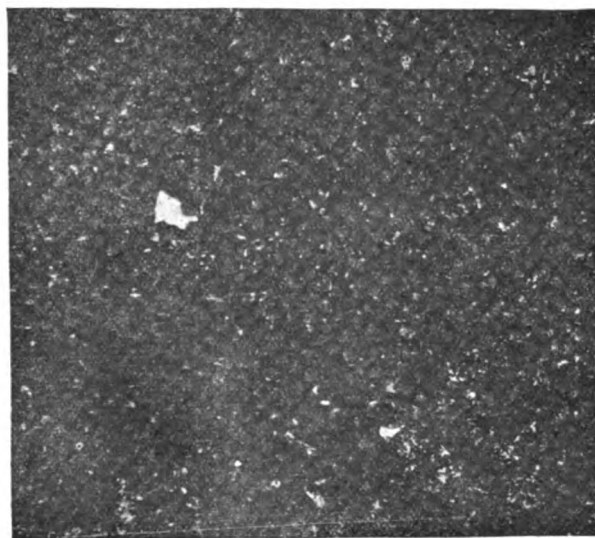


Fig. 6.

three factors, rate of cooling, position of the transformation temperature and degree of transformation. It should also be stated here that in an important paper by Portevin and Garvin* the authors, while noting the gradual lowering of the temperature of transformation caused by increasing rate of cooling, are led to believe in a discontinuity of the phenomenon when the cooling is very rapid as in quenching, and to conceive the existence of what they term "critical speed of quenching." In their opinion the lowering of the point is gradual only so long as it occurs above 600 degrees C. This conception calls for the occurrence on quenching of a thermal point at about 650 degrees C, which they call A_2 , indicating the formation of troostite and of a second point called

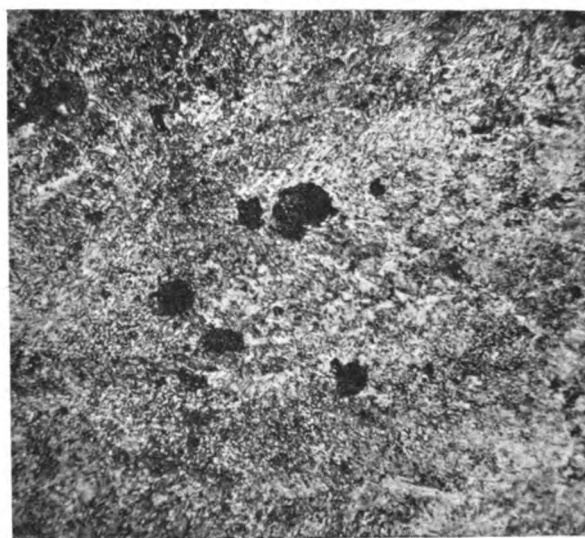


Fig. 7.

*The experimental investigation of the influence of the rate of cooling on the hardening of carbon steel.—A. M. Portevin and M. Garvin Journal Iron and Steel Institute, No. 1, 1919, page 469.

Ar, in the vicinity of 300 degrees C, corresponding to the formation of martensite. Steels exhibiting these two points contain both troostite and martensite; those for which the upper point, Ar', only occurs are entirely troostitic, while those exhibiting the lower point, Ar'', only are entirely martensitic. It is also noted by the authors that the thermal point at 650 degrees C corresponds to a distinct jog in the cooling curves while the evolution of such occurring in the vicinity of 300 degrees C is much more gradual, causing merely a change of direction of the cooling curve. For a certain rate of cooling (the critical rate) the upper point abruptly disappears while the lower one persists or makes its appearance.

Should further investigations confirm the accuracy of this brilliantly worked out conception the diagram herewith submitted which the author has used for years in his teaching would have to be modified accordingly. Pending his confirmation its use in illustration of the remarks of this paper appears justified.

The very frequent occurrence of both martensite and troostite in the same sample of quenched steel is not explained in a fully satisfactory manner by Portevin and Garvin's theory seeing that it de-

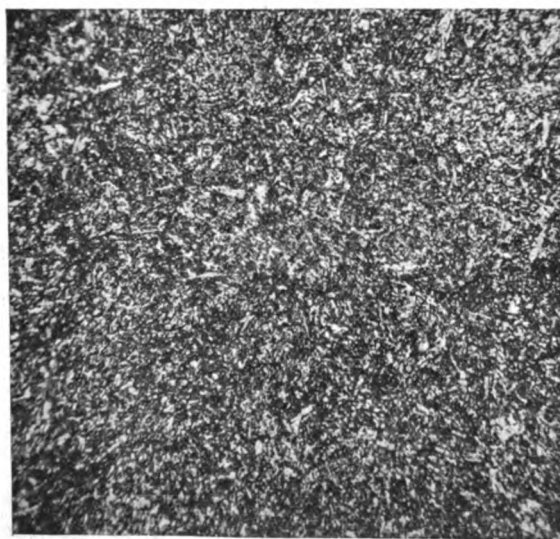


Fig. 8.

mands the occurrence of the two points Ar' and Ar'' implying the transformation into troostite at 650 degrees C of a portion of the austenite and the transformation into martensite of the balance of 300 degrees C. Without discussing the matter further let it be observed that this theory also indicates that the structure of steel depends primarily upon the extent of the transformation which in turn depends upon the temperature at which that transformation takes place.

Sorbite is more tenacious, harder and less ductile than pearlite; troostite is more tenacious, harder and less ductile than sorbite; martensite is more tenacious, harder and less ductile than troostite. When maximum softness and ductility are needed, therefore, the treatment should be of such a nature as to permit the steel to become pearlitic which in turn implies a transformation at about 700 degrees C, hence, slow cooling. Such treatment is generally known as "annealing."

To produce greater tenacity and elastic limit with reduced ductility although retaining freedom from brittleness, the metal should be made sorbitic through

a suitable rate of cooling, by which the position of the critical point will be sufficiently depressed.

To produce great hardness, necessarily accompanied by little ductility, if not by brittleness, the steel should be made martensitic or troostite-martensitic which implies cooling at such rate that the temperature of transformation is lowered to about 300 degrees C. These three basic treatments may be called, respectively, "Softening," "Strengthening" and "Hardening" treatments. It is obvious that the gradual transformation of one constituent into another, as for instance, of martensite into troostite may result in the presence in the metal of these two constituents in an infinite number of proportions, hence that the physical properties of steel may be made to vary by an infinite number of steps.

The physical properties of steel, however, do not depend exclusively upon the relative proportions it may contain of the micro-constituents mentioned above; they also depend upon what may be termed "the fineness of the structure." In other words steel may be finely or coarsely pearlitic, finely or coarsely sorbitic or martensitic, when it will be found in nearly every case that the finer structure is preferable. Hence, the desirability of producing not only the necessary constituents but of obtaining them in the finest possible form. This is why, for the purpose of heat-treatment, the steel should not generally be heated to a temperature much above its critical range. Again, in steel so generally, although, vaguely, described as "heat treated," the aim is generally to produce a sorbitic condition in order that the metal may be highly tenacious, but this condition is not as a rule imparted by a single cooling through the range at the proper rate because such treatment while producing sorbite will not yield it in a sufficiently fine condition. It is preferable to have recourse to an indirect treatment consisting in first producing martensite through a faster cooling and then in transforming that constituent into sorbite by a so-called "drawing treatment," because the very fast cooling needed to produce martensite implies a finer structure and this fineness of structure is retained when martensite is tempered into sorbite.

Passing now to alloy steels, metallographic methods of investigation again supply the key necessary to understand the remarkable properties of some of these alloys and the influence of heat-treatment. It has been found that some elements such as manganese, nickel, chromium, tungsten and others when alloyed with iron and carbon yield results to which these alloys owe their great industrial importance. It may be asserted that were it not for the marked influence of the elements in lowering (or raising) the position of the temperature of transformation they would have comparatively little, if any, influence on the physical properties, and alloy steel, therefore, would be of little importance. If manganese steel, for instance, had its transformation temperature on slow cooling at the ordinary temperature, that is, in the vicinity of 700 degrees C, the steel would become pearlitic on slow cooling and would not therefore differ materially from ordinary slowly cooled carbon steel. Manganese, however, lowers the point of transformation causing that transformation to take place at gradually lower temperatures and therefore causing the steel to assume on slow cooling the various structures described above and which in carbon steel can be obtained only, if at all, by increasing the rate of cooling. When, for

instance, a sufficient proportion of manganese or nickel has been introduced to lower the temperature of transformation to some 300 degrees C, the steel, although slowly cooled, becomes martensitic. Indeed with some of these elements it is possible to prevent the transformation altogether retaining the steel in its austenitic condition. Obviously in such cases no thermal critical point occurs above room temperature. The influence of some of these alloying elements, therefore, is to produce after slow cooling, structures which in carbon steels can be obtained only by rapid cooling (quenching), if at all. The advantage of obtaining sorbitic or martensitic structures without having recourse to quick cooling is obvious because of the inherent dangers of the quenching bath.

To clarify, steel to become martensitic must have its transformation lowered to some 300 degrees C. This can be accomplished in carbon steel (provided enough carbon be present) by quenching, while in some alloy steels it is produced through the addition of a sufficient amount of the special element without the necessity of quenching. Such steels are frequently referred to as "air" or "self-hardening" steels.

A third factor is sometimes effective in lowering the temperature of transformation sufficiently to produce martensite, namely, increasing the temperature from which cooling begins. Some nickel chromium steels, for instance, which after slow cooling from a temperature slightly above the normal position of their critical point, are pearlitic or sorbitic, may become martensitic if the cooling proceeds from a considerably higher temperature. It is observed then that as the temperature from which cooling begins increases, the position of the critical point is lowered until when it reaches some 300 degrees C., martensite is produced. In some cases the normal thermal critical point occurring in the vicinity of 700 degrees C. on slow cooling from slightly above the critical range seems to gradually disappear as the temperature from which cooling begins increases, while a new point occurs in the vicinity of 300 degrees C. increasing somewhat in intensity as the temperature from which the metal cools increases. This is what happens in the heat-treatment of high speed steel. It remains true however, that steel becomes martensitic whenever the temperature of transformation is lowered to about 300 degrees C., whether this be accomplished by quenching or through the influence of the special element or elements assisted or not by increasing the temperature from which cooling begins.

In regard to the formation of martensite, steels therefore may be divided into the following classes:

Water hardening steel, that is, those steels which in order to become hard must be quenched in water as for instance, medium high carbon steels.

Oil hardening steel, that is, those steels which become hard after quenching in oil as for instance high carbon steels.

Air hardening steel, that is, those steels which become hard after air cooling as for instance, some nickel chromium steels, some nickel steels, some manganese steels, etc.

Furnace hardening steel, that is, those steels which become hard even after very slow cooling in the furnace as for instance, some nickel and some manganese steels.

Air hardening and furnace hardening steels are sometimes called "self" hardening steels.

The question may well be asked, however, whether the martensite formed under these different cooling conditions should be identical in structure and physical

properties seeing that this constituent may have formed (1) very quickly in water quenching, (2) more leisurely on air hardening, or (3) very leisurely on furnace cool-

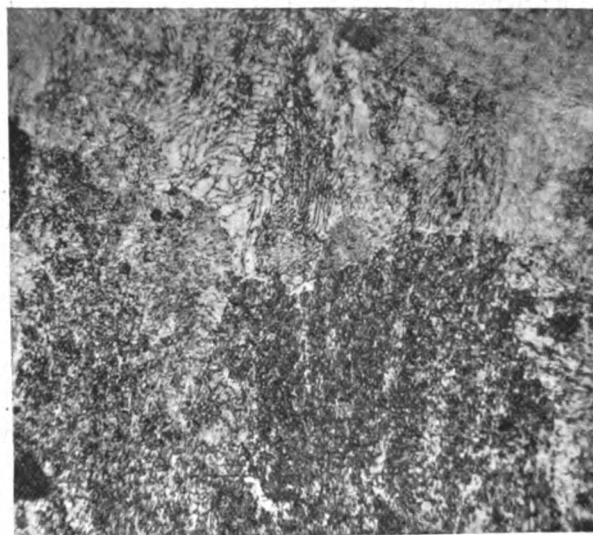


Fig. 9.

ing. Indeed it is apparent that martensite produced on slow cooling is more stable than the same constituent obtained by rapid cooling. Carbon steel for instance, made martensitic by quenching can be readily tempered and softened while self-hardening steel made martensitic by slower cooling requires prolonged heating to some 600 degrees to 675 degrees C. to be softened. This is why some of these self-or-air-hardening steels were used successfully as cutting tools before the introduction of high speed steel. They could be used at greater speed than quenched carbon steel without losing their cutting edge through the tempering action of the heat of friction. Their martensitic condition was more stable. Furnace hardening steels which become martensitic after furnace cooling should retain their cutting edge when heated to still higher temperature and should therefore

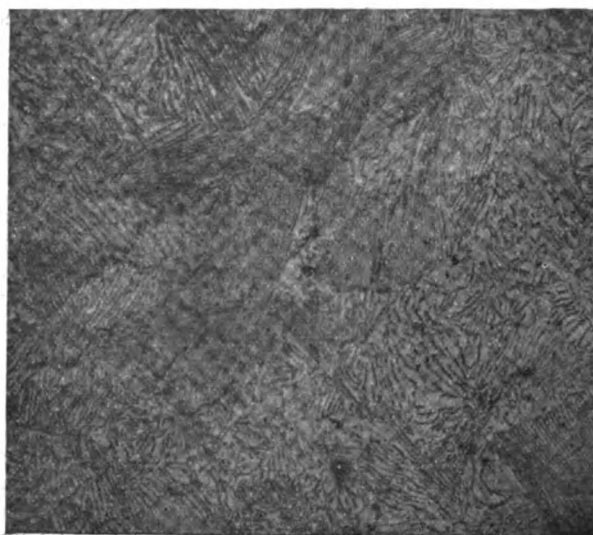


Fig. 10.

possess some of the essential properties of high speed steel. Obviously then the condition of any hardened steel is the more unstable, that is, it yields the more

readily to tempering and drawing, not only the more incomplete its transformation but also the faster the cooling that produced this partial transformation. To illustrate martensitic carbon steel is more unstable than the same steel in a troostitic condition because it is less completely transformed: martensitic air hardening steel is more stable than martensitic carbon steel because the martensite of the former resulted from a slower rate of cooling.

The microscopic study of steel has made possible, improvements and refinements in the heat-treatment of that metal which could not have been accomplished with-

out its aid. It seems hardly necessary to call the attention of the members of this institute to the important part played by the microscope in those plants where steel must be subjected to careful heat-treatment as for instance in the manufacture of automobiles, aircrafts, etc. It has made possible that reduction in weight so essential in those constructions a reduction which can be obtained only by so treating the different parts as to obtain maximum properties for each pound of steel used. Employers from these plants have sought instruction in metallography by the hundreds if not by the thousands.

Ash Disposal in Modern Power Plants

Advantages and Disadvantages of Various Types of Ash Disposal Systems—Types of Conveyors—Engineering Study Necessary for Each Particular Installation.

By GUY S. HAMILTON,
American Steam Ash Conveyor.

A YEAR or so ago, one of our well known power plant publications described the ash handling equipment in the power plant of a well known educational institution—a state school with a progressive reputation.

Of special interest was the description of the ash handling equipment installed in this plant. Describing it, the article stated:

"The ash handling equipment is located in the basement; beneath the stokers is a horizontal drag chain conveyor 48 feet between centers, into which the ashes are discharged. It runs at a speed of 60 feet per minute and has a capacity of eight tons per hour. The ashes are carried along by the bottom strand in a cast-iron trough, the returning strand of chain being carried on angle iron guides at the top. This conveyor discharges the ashes into a vertical elevator, which passes up through the main boiler room to the ceiling and there empties the ashes into a spiral conveyor by which they are delivered to the steel storage bin outside. This bin, which can be seen in the foreground in the headpiece, is elevated at the bottom with a large clam shell valve through which the ashes may be discharged. The entire ash-handling unit is driven by one motor, so that all sections start at the same time."

It is to be supposed that equipment installed would be of the first order from a point of engineering design, yet when the conveyor equipment is analyzed three types of conveyors were used to handle the ashes from stoker pits to ash tank outside:

1. A drag chain conveyor.
2. A verticle elevator.
3. A spiral gravity conveyor.

It is evident that the engineer in charge of the design had not studied very seriously the subject of ash disposal engineering. Had that been the case he would have chosen some simpler type of equipment to do this work.

There are many kinds of equipment now in use as ash conveyors. Some of these fill their requirement ideally. Others are make-shifts or are the results of persuasion on the part of over zealous salesmen to force a conveyor on a trusting but uninformed engineer.

Ash disposal is a subject in itself. Its importance should not be minimized. Upon the correct design of ash conveying machinery often depends the efficiency and economical operation of the plant.

So important is the subject of ash disposal that it should always be left to experts. The engineer designing the plant should call into consultation ash disposal engineers whose entire training has been on this subject. Only by so doing will the ash handling design be in keeping with the rest of the plant.

The type of equipment of course will depend on the plant conditions. The location and number of boilers, the type of stokers, the amount of horsepower developed, the kind of coal burned, the general plant arrangement—all must be taken into consideration by the ash disposal engineer. There are however, certain outstanding facts about various types of equipment that can properly be discussed and it will be the mission of this paper to numerate and comment on them.

The oldest and the most primitive forms of ash disposal are of course the wheelbarrow and ash can. Aside from the expense due to labor it is practically impossible to keep men on this back-breaking job when they can obtain other kinds of employment. The wheelbarrow type of ash handling is found even in otherwise modern plants.

Mechanical methods are of numerous types. Some types can be condemned outright; others have points of merit. A resume of the field reveals the following types which are in familiar use:

- Flight conveyors.
- Pan conveyors.
- Belt conveyors.
- Pivoted bucket conveyor.
- Monorail conveyor.
- Bucket and chain elevator.
- Skip hoist conveyor.

Flight Conveyors.

While there are almost numberless different forms of flight conveyors, the essential elements are the same in all forms. The flight conveyor consists of a series of equally spaced flights, drawing through a trough by

means of some form of chain. In this conveyor a single strand of chain is used, which is connected to the center of the flights by some form of attachment link. The flight is provided with an iron wearing shoe at each side, which supports and guides the flights on the angle iron track, provided at each side of both the carrying and return runs. The weight of the chain is also transmitted through the flights to these wearing shoes. The distance between the return run and the carrying run can be varied to suit different conditions.

As the entire weight of the flights and chain is carried on the wearing shoes which drag on the track, a considerable saving in power and wear can be effected by using rollers instead of wearing shoes. The initial cost of such a conveyor is, of course, greater than where wearing shoes are used. The trough is practically the same for either of these conveyors, being made up of pressed steel usually $\frac{1}{4}$ inch thick. Intermediate discharge points may be obtained by cutting away the bottom of the trough at these points and providing either a slide or drop gate at that point, which can be opened when discharge is desired, and over which the material is conveyed when the gate is closed.

It is obvious that where a single strand of chain is used that there still be a tendency to twist the flight about the central axis of the chain, if the flight is made of any considerable width. As the carrying capacity of the conveyor depends directly upon the area of the flight, a large flight would also necessitate a larger, heavier chain. For these reasons, where a large flight is necessary, two strands of chain are used, and the rollers are incorporated as a part of the chain itself. This form of conveyor is shown in Fig. 4. The double strand conveyor is nearly twice as high in initial cost as the single strand, owing to the fact that twice as much chain is required, also double the number of sprockets. The roller chain used on the double strand conveyor is also more expensive than the chain used in the single strand conveyors.

Pan Conveyors.

Pan conveyors may be considered as a refinement of the drag conveyor. In the pan conveyor the flights are omitted and the trough itself is made in sections and mounted on the chain. By this change the material to be conveyed is actually carried in the trough instead of being dragged through it. The consequent reduction in wear on the trough is obvious. A true pan conveyor is made up of a series of cast iron pans supported by rollers and mounted on a single strand of chain. The entire conveyor is carried on steel tracks. As the pans must be stiff enough to support themselves and the load carried, they are generally made of cast iron when used for handling abrasive material. Steel, unless quite thick, would give sufficient stiffness and would be more quickly worn out by the abrasive material.

All forms of pan conveyors are too expensive, both in initial cost and maintenance, for the economical handling of ashes.

Belt Conveyors.

The belt conveyor is merely a continuous belt of canvas or rubber on which the material to be carried is deposited and either discharged over the head pulley or, at intermediate points through a specially designed tripper or unloader. In order to increase the carrying capacity of the belt and to prevent spilling, the edges of the belt are turned up by some form of troughing roller. In order to properly support the carrying belt, these troughing rollers must be installed at an average spacing of five-foot centers. The return belt is supported below the

carrying belt on flat rollers, which may be spaced 10 to 12 feet centers. On long belts it is necessary to install guide rollers at the edge of the carrying belt, at intervals of 30 to 50 feet centers, to keep the belt traveling in a straight line.

As the material is actually carried on the belt, it is possible to operate the conveyor at a much higher speed than is the case with the drag conveyor, or any other type of carrying conveyor. The capacity of belt conveyors is, therefore, relatively much greater than any other type of mechanical conveyors.

It is readily seen that owing to the number of troughing rollers and return rollers required, as well as the driving machinery and supports, that this type of conveyor is quite expensive to install. The belts used for this purpose are specially made and are very expensive.

This type of conveyor should never, under any circumstances, be used for the handling of ashes for the following reasons:

First—Initial cost of installation.

Second—Ashes must always be thoroughly quenched before being placed on the belt, as no successful fireproof belt has ever been developed.

Third—It has been found by experience that where belt conveyors are used for ash handling, that on account of the extremely abrasive nature of the ash, it is necessary to replace the entire belt about every six months. The cost of maintenance is therefore entirely too high to justify the use of this type of conveyor for the handling of ashes.

Pivoted Bucket Carriers.

The pivoted bucket carrier is composed of a continuous series of malleable iron buckets pivoted between two strands of roller chain, of approximately 18-inch pitch. There are several different forms of this carrier on the market. The difference in these buckets are principally in the method used to empty the buckets at the discharge point, the method used to close the gaps between adjacent buckets to prevent spillage, and the method of driving the conveyor. In one form of carrier the buckets are made with an overlapping lip, in a second form a roller is introduced between adjacent buckets, etc. The roller chain is carried and guided by a track composed of standard light tee-rail. This rail is mounted on special cast iron rail chairs, both horizontal and vertical runs. The buckets can be dumped at any desired point by means of an adjustable dump mechanism, which may be set wherever desired.

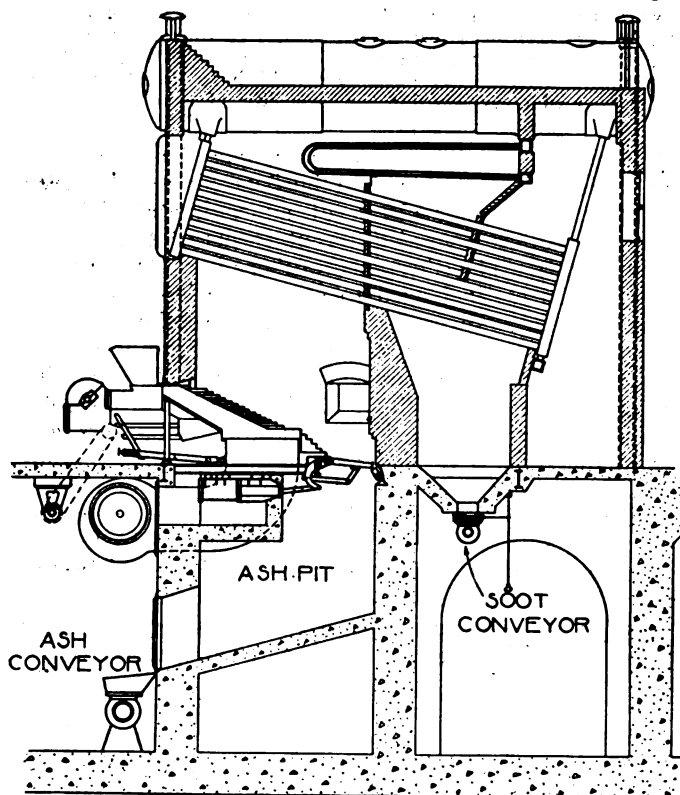
As the buckets are pivoted and always remain in the horizontal position except when being dumped, this conveyor can be used for handling material both horizontally and vertically. The pivoted bucket carrier is generally installed in power plants, so arranged as to handle both coal and ashes in the same carrier. It is installed in the form of a loop, running through the basement, up one end of the boiler house, over the top of the overhead coal storage bunkers and down the other end to the basement. Coal is discharged from the receiving track through a track hopper, feeder and crusher, into the pivoted bucket carrier in the basement, and carried up to the overhead storage bunkers. Ashes are raked or dropped from the ash pits into the horizontal run in the basement and carried up to an overhead bunker for storage.

The pivoted bucket carrier is the best known form of handling coal in a power plant. Coal dust is an actual lubricant to all wearing parts of the conveyor, and if ashes are kept out of the conveyor, all parts of the carrier will wear for a very great length of time. This carrier is the most expensive form of mechanical conveying equipment, and the handling of ash in this type of apparatus might be compared to the use of an expensive

touring car for trucking purposes. It is absolutely impossible to prevent wear on the chain due to the abrasive dust from ashes. A great many plants in which this apparatus has been installed for the handling of both coal and ashes have been compelled to install some other form of apparatus to handle the ash in order to prevent the expense and delay caused by the breaking of chain, and wearing out of moving parts. In a large plant the pivoted bucket carrier is generally needed continuously for the handling of coal and cannot be tied up in handling ashes. It has been found absolutely necessary, by long experience to divorce the handling of coal and ashes, installing separate equipments for each purpose.

Monorail System.

The monorail system of handling material consists primarily of an overhead track carrying a trolley or carriage on which is mounted a hoist for handling a bucket of large capacity ($\frac{1}{4}$ to two or three tons). Both hoisting and travel may be accomplished by either hand or electric power. Standard I-Beam sections are usually employed for the track, which can be equipped with single or multiple point switches, wherever desired, giving



Cross section of boiler showing ash conveyor systems.

ing great flexibility in a horizontal plane. These switches can be operated from the ground.

Where electric power is used, the hoist and carriage are made in two forms. One form is controlled, both with regard to hoisting and travel, from the ground, and it is necessary for the operator to walk with the carriage when it is traveling along the track. In the other form, which is used for large capacity, a carriage in which the operator rides is attached to the trolley and both hoisting and travel are controlled from this carriage. This is one of the best forms of ash handling equipment for use where ashes are produced in large quantities and are to be carried to a considerable distance from the plant. It is also an exceptionally good method for taking care of

large, hard clinkers, which cannot be broken small enough to be handled in other types of conveyors. For this reason, it is particularly adapted to use with gas producers or other furnaces in which large clinkers and wet ashes are produced. In installing this class of equipment, the tracks should be so arranged that the bucket can be dropped directly into the ash pit or directly in front of the ash door in hand-fired plants. The buckets should also be of sufficient capacity to remove the entire accumulation of ashes in one pit at one loading.

Where chain grates, or stokers similarly equipped with hoppers are installed, the same apparatus can be very successfully used for the handling of the coal.

Where it is necessary to carry the ashes from a large plant to a distance greater than 150 or 200 feet beyond the house, the monorail system is probably the most successful system that can be employed.

Bucket and Chain Conveyor.

For hand operation, a standard chain hoist is suspended from the trolley. The trolley is also equipped with a chain-operated drive for moving it on the track. For a comparatively small plant, where the necessary travel is not great, this hand power equipment can be successfully employed for the handling of both ashes and coal. It does not, however, give the greatest saving of manual labor, as ashes must be shoveled from the boiler or ash pit into the bucket. There are certain conditions which warrant the installation of this equipment in small plants, but all possible points should be considered by experts in ash handling before a definite decision is reached.

Skip Hoist.

The skip hoist is one of the oldest methods of elevating materials. This apparatus, in simple form was in general use in the Kimberly diamond fields, and is often spoken of, especially by mining men, as the "Kimberly Skip." The skip, as used in the diamond fields, consisted of an open-end car running on an inclined track from the bottom of the pit to the top of the dump pile. At the top the track was dropped suddenly around a curve so that the car was inverted and the contents dropped on the dump pile. This form of skip is used, in a greatly improved form, for charging the blast furnaces in all steel plants, and for handling ashes where the conditions demand an inclined hoistway.

The skip hoist, is fundamentally, a bucket or car, of the proper capacity to meet conditions, so arranged as to be quickly hoisted to the dumping point, automatically tipped to discharge the load, and returned to the loading point. The track, or hoistway, may be either vertical or inclined to suit local conditions.

Probably the first general use of the vertical skip hoist was for elevating coal to the storage pocket in railroad coaling stations. This type of coaling station is now almost a standard, owing to low operating cost and maintenance. In the vertical skip it is found more practicable to mount the bucket or car in a separate frame, to which it is pivoted, than to change the direction of the guiding track. By this arrangement the pull of the hoisting rope is always the same (vertical) direction.

The bucket frame runs between two guides which extend the entire height of the hoistway. The bucket is so pivoted, with reference to its center of gravity, as to be held in the upright position by its own weight, and the weight of the load. At the dumping point, near the top of the hoistway, is located a separate, curved guide which

engages a roller on each side of the bucket, pulling the bucket into the dumping position:

The car and skip hoist system should never be considered for installation in a plant that is not provided with ash pits from which the ashes can be dumped directly into the car. Otherwise too much labor is required for loading the cars.

The typical installation may be described as follows:

The boilers are installed in two rows, and are provided with ash pits from which the ashes can be dumped directly into industrial cars in the basement. Two tracks are required to bring these cars to the ash pits, but the tracks are both brought to the loading point of the skip hoist.

The filled car is pushed to the foot of the hoistway and the ashes dumped into the skip bucket. The operator then pushes the electric control button and goes back with the industrial car for another load. As soon as the control button is pushed, the electric hoist is automatically started, and the skip bucket is raised to the dumping point. The arrival of the bucket at the dumping point automatically stops the hoist and operates a solenoid brake which holds the bucket at the dumping point for a predetermined length of time. This length of time can be regulated by adjustment of the automatic control. Having remained at the dumping point long enough for the ashes to be emptied, the bucket automatically returns to the foot of the hoistway and stops, ready for another load. It is to be noted that the operator does not need to waste time waiting to stop the hoist when the bucket reaches the top or bottom, but can be getting another load of ashes while the hoisting and dumping are taking place.

If the hoistway passes through a clean boiler room it should be enclosed all the way to the top to prevent possible spilling of ashes into the room. If it is entirely outside of the building, it is not necessary to enclose the hoistway except at the top. It should always be enclosed above the roof of any building through which it passes, to keep rain and snow out of the building.

The chute to the storage bin should be lined with hard cast iron to take care of the wear on the bottom, due to the sliding ashes.

The advantages of this system of ash handling are:

First—Capacity. This method is especially adapted for plants producing large quantities of ashes. The usual industrial car is of one-ton capacity, and the capacity of a corresponding skip hoist would be from 10 to 25 tons per hour, depending on height, etc.

Second—The car and skip method is about the only successful method for handling extremely large and hard clinkers. The clinkers handled by this system need little breaking.

Third—Power is used only when ashes are being actually hoisted, and is not wasted while ashes are being brought to the hoist.

Fourth—The skip hoist can easily be designed and constructed so that it can be loaded or dumped at different levels. In this way it is possible to handle ashes from boilers on different levels in the same hoist, and also to discharge at different elevations.

Fifth—As the ashes come in contact with no moving part, the only wear is on the discharge side of the bucket and on the bottom of the discharge spout. Maintenance is therefore exceedingly low, per ton of ash handled.

The disadvantages are:

First—The initial cost of such an installation prohibits its use in any but the largest plants.

Second—The ashes must be moved from the boilers to the hoist by manual labor.

Third—The electric control must be inspected and maintained by a competent electrician.

For plants producing too great a quantity of ashes, or having clinkers too large and hard for the steam jet

conveyor, the industrial car and skip hoist will give the ideal equipment.

It is becoming quite common practice, in very large plants, to install boilers on the second floor of the plant, with ash pits of ample capacity underneath. A railroad track is installed, on the ground level, directly under the ash pits. The ashes are dropped, through large doors or gates, directly into railroad cars.

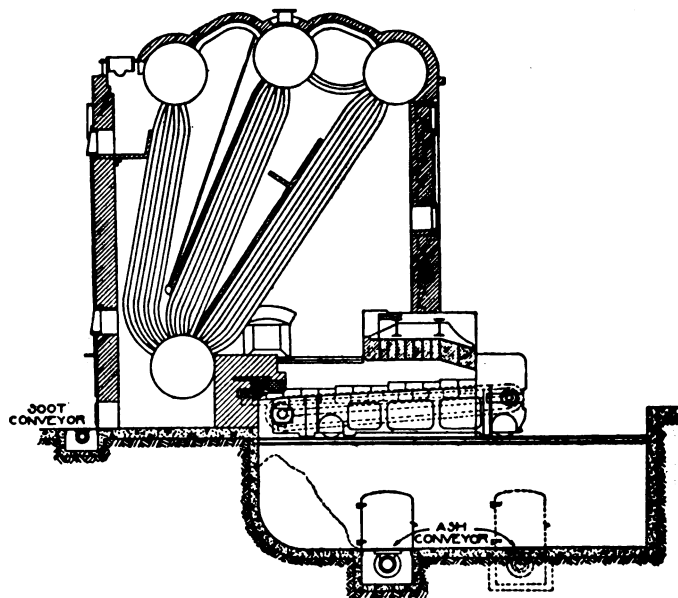
This is the most successful, and simplest way of handling ashes from a large plant. The objections to this method are:

First—Trouble in obtaining cars as required.

Second—Very great expense in raising the complete boiler plant to the second floor instead of installing on ground level.

The Steam Jet Conveyor.

This conveyor consists, primarily of a line of pipe into which ashes are fed, and through which they are carried to a discharge point by current action. The steam jet conveyor suction is employed only in the line immediately in front of the boilers, or ash pits, in what is known as the "suction line." The extreme end of the



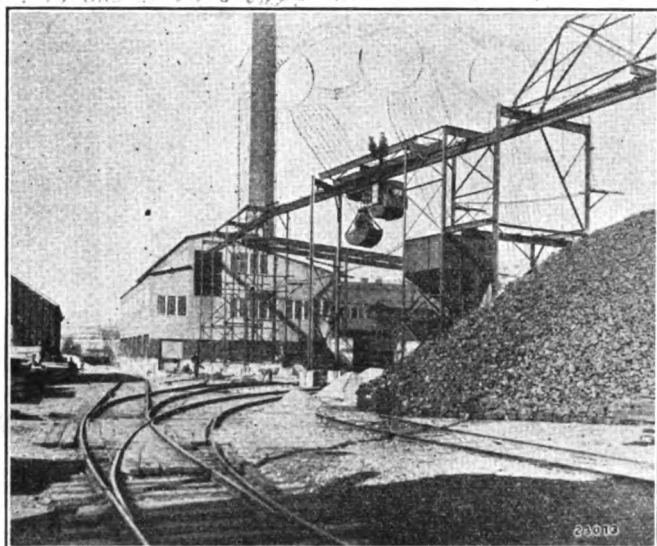
Boiler plan showing another ash conveyor installation.

suction line is provided with an air intake. The line beyond the suction line is called the "discharge line." The discharge line may be a continuation, in a straight horizontal line, of the suction line; may rise at any angle to the discharge point, or may rise vertically from the end of the suction line, through what is called the "riser," to an upper, horizontal discharge line.

The suction is created in the suction line by the action of a jet of high velocity steam discharged into the center of the pipe line, in the direction of travel of the ashes. This steam discharge tends to create a vacuum behind it, which in turn creates a current of air through the air intake at the end of the line. The steam jet is applied to the conveyor by means of a "steam unit fitting," in which is inserted a specially designed "nozzle," or nozzles. This steam unit may be of the "straight-line" variety, for use in a perfectly straight run, or it may be made of any desired angularity. In the angular steam units only one nozzle is necessary as it can be inserted in the end of the fitting, discharging directly down the center line of the discharge pipe. In the straight-line fitting

two nozzles are used, inserted on opposite sides of the fitting at the proper angle so that the resultant of the two jets will be down the center of the pipe, without the production of swirling, or eddy currents. The effective suction distance of one steam unit, is, of course, limited, and if this distance is exceeded in the length of the suction line, it is necessary to install additional "booster" steam units. These booster units are always straight-line fittings unless a necessary bend in the suction line allows the use of an angle fitting.

The discharge of the ashes beyond the steam unit is really an ejection due to the force of the steam jet actually pushing the ashes through the pipe. The effective discharge distance of a steam unit is much greater than its suction distance, therefore in the average system no additional steam units are necessary in the discharge line. The actual number and location of steam units can only be determined by experts who have had experience in the design, installation and operation of these conveyors.



Method of coal handling. The coal in this case is unloaded from cars to stock pile and may be taken from either cars or stock pile directly to the boilers. This is all done with a minimum amount of labor as the services of but one man is required. A Hayward clam shell bucket with regular bowl in this case is operated by an overhead system which is clearly shown by the photograph.

There are three methods of discharge from a steam jet conveyor: Open distance discharge, baffle box, and storage bin. The open discharge is usually used where it is desired to fill a gully, or other low ground, and where the blowing of ash dust will not be objectionable. In this method of discharge, the ashes are merely blown from the end of the pipe without any restraint. As the ashes are blown 50 to 75 feet beyond the end of the pipe, some ash dust will be carried over the neighborhood, even when the most effective water jet is installed in the line. This method has been found perfectly satisfactory for use in coal mines and similar plants.

In order to confine the discharge to one point, such as a car, wagon, etc., a baffle box is used. This baffle box must be properly designed to take the impact of the discharged ashes without undue wear, and to discharge the ashes without packing. By the proper design of all details this system will not cause any trouble due to dust

in plants located in manufacturing districts. The great objection to this method of discharge is the lack of storage, and the fact that a car or wagon must be held until sufficient ashes are obtained for a full load.

In plants where ash storage is desired or where the plant is located in a residence or business district and absolute freedom from dust is essential, an ash bin must be installed. All of the feature of this method of discharge will be discussed under the subject of bins.

In selecting a steam jet ash conveyor the following points should be given careful consideration.

Material—The metal in the conveyor should be the hardest that can be manufactured, to stand the abrasive action of the ashes. If the metal is of the proper hardness it is impossible to machine it in any way. The use of the proper metal in the steam nozzles is one of the most important points in the manufacture of a steam jet conveyor.

Joints—The joint in the pipe should be so designed as to be easily and quickly installed and should result in a joint that is not only steam and airtight when installed, but will remain so during the entire life of the pipe or fitting. In other words, the joint should remain tight until the pipe is worn entirely through. This is only possible with a full flanged pipe having gasket material extending the full width of the flanges.

Ash Intakes—The ideal intake fitting should be so designed that all of the wear due to the first impact of the ashes is taken inside of the fitting and not on the pipe beyond the fitting. The fitting should also be provided with renewable liners designed to protect the body of the fitting from wear. If the fitting is installed ahead of a booster steam unit, the cover should be heavy enough to prevent its being blown off, and should be deep enough and of the proper shape to fill out the exact contour of the inside of the pipe. The cover should, of course, make a practically airtight joint with the top of the fitting.

Wear—In considering the life of a liner or fitting, the actual amount of ash handled over the part should be considered, and not the length of time the part was installed in the line. In other words, always figure cost of maintenance as a certain amount per ton of ash.

All fittings should be designed so that all points subject to extreme wear are protected by renewable liners, easily removed and replaced without removing the body of the fitting from the pipe line. As the greatest wear on straight pipe occurs on the bottom of the pipe, the system should be so designed as to allow the pipe to be easily turned and worn on all sides, but still maintaining a smooth bottom surface at all joints.

Unnecessary turns in the line should be eliminated to keep steam consumption and maintenance at the minimum.

Water Jet—A water jet should be installed in the discharge line of all conveyors discharging into the open, or into a baffle box. This jet should supply just enough atomized water to settle the dust without making the discharged ashes really wet, so that they will pack or freeze. The proper location of the water jet can only be determined by experience.

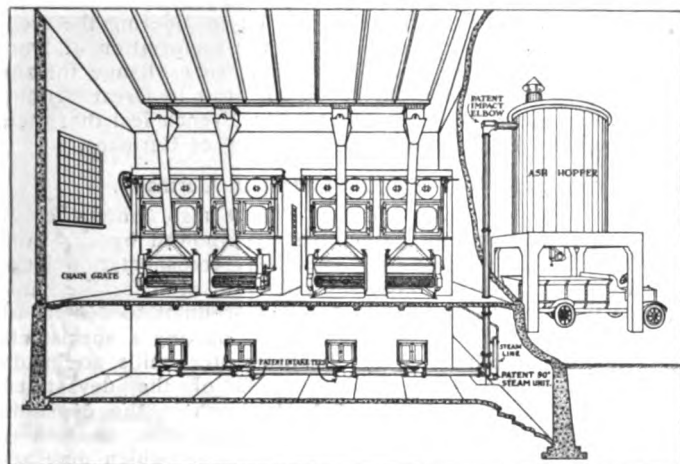
Steam Consumption—The size of the steam nozzles should never be determined by guess, but by actual scientific test when the conveyor is started in operation. This is one of the greatest factors in keeping steam consumption at the minimum.

While the steam consumption of a steam jet conveyor is, at first glance, quite large, the ashes are moved so quickly that the steam per ton of ash handled is quite reasonable in a conveyor properly designed and installed. In comparing power consumption with that of other types of conveyors, the power should always be figured back to pounds of steam at the boiler, taking into consideration all losses from the boiler to the point of application. Thus a mechanical conveyor requiring a certain number of horsepower to drive by means of an electric motor, will not appear to such advantage when the power is figured back to pounds of steam per ton of ash handled.

A steam jet conveyor should be operated at a time when the other load on the boilers is lightest, such as during the noon hour, early morning, etc., depending on conditions in the plant.

Ash Storage Bins.

With any type of ash conveyor except the vacuum and steam jet conveyors, any kind of a receptacle can be used for the storage of ashes, the only consideration being that of strength. With the vacuum conveyor the



Steam jet ash conveyor installation.

only additional consideration is that the bin must be airtight. With the steam jet conveyor a bin must be so designed that,

First—Absolutely no dust will be discharged with the exhaust steam.

Second—No trouble will be caused by water of condensation, resulting from discharging steam into a cold bin.

Third—No water shall be allowed to come in direct contact with the ashes in the bin.

Fourth—Ashes shall be discharged into the bin without any remaining downward component of the conveying force, thus preventing packing in the bin.

Fifth—The impact of the discharged ashes must be taken by a suitable baffle, which will give the maximum wear. Ashes discharged against the wall of any kind of a bin will cut a large hole entirely through the wall in a few hour's operation.

All of the above points can be successfully taken care of by proper design.

Caution.

The apparent simplicity of the steam jet conveyor often leads engineers to think that they can build and install such a conveyor themselves. This is a great mistake, as there is no power plant apparatus requiring more expert, experienced attention, to give satisfactory results, than the steam jet conveyor. The purchaser of a con-

veyor should remember that he is not buying pipe, but is buying experience, ability, service and the use of patented features as well as material. Even the oldest manufacturers of this type of conveyor are continually improving their apparatus as the result of experience gained by studying conveyors in years of operation. As no two ash handling problems are ever the same, it is impossible to make the steam jet conveyor a standardized piece of apparatus, and a successful system can only be designed by those with great experience on which to base their design.

The disadvantages of the steam jet conveyor are:

First—Necessity of breaking clinkers small enough to pass through the intake opening. In the great majority of cases the clinkers encountered are very easily broken, as the ashes are raked in to the intake, by merely striking them with a hoe. In other cases where very hard clinkers are encountered, the clinkers form a comparatively small proportion of the total ash, and can easily be removed by hand while the smaller ash is taken care of by the conveyor. In very rare instances the ash produced is almost entirely made up of very large, hard clinkers. In these cases the steam jet conveyor should not be considered as a means of ash disposal.

Second—Steam Pressure. It has been found by experience that the steam jet conveyor cannot be successfully used with a lower steam pressure than 60 pounds per square inch. This absolutely prohibits its use in low pressure plants.

Third—Wet Ashes. Generally speaking, wet ashes cannot be handled in the steam jet conveyor on account of the ashes packing at the turns of the line. As it is in no way necessary to wet the ashes before feeding them into the conveyor, this can only be considered a disadvantage when the ashes are wet when produced, as in the water-sealed gas producer, etc. Even certain kinds of wet ashes can be successfully handled, therefore experts on this type of apparatus should be consulted before a decision is made as to the method to be used.

Fourth—Limited Capacity. There is, of course, a limit to the amount of ashes that can be successfully and economically handled in one conveyor. As this limit depends upon so many factors, the problem of capacity should also be submitted to unprejudiced experts. In some large plants several conveyors, discharging into the same or different bins, have been installed, keeping the limit per system to a safe maximum.

The advantages of the steam jet conveyor are:

First—Flexibility. The steam jet conveyor is very flexible and can be installed in any plant, no matter how crowded.

Second—Ease of Installation. This is one of the easiest ash-handling systems to install. With the instructions and drawings furnished by the manufacturers the purchaser can erect all of the material himself, without the services of any expert erection men.

Third—Simplicity. No skilled labor is required to operate this conveyor. Operation consists only of turning on the steam and raking the ashes into the intakes in turn.

Fourth—Low Initial Cost. This is one of the cheapest systems to install on account of its simplicity and ease of installation. Its cost, however, should not be compared to the price of standard pipe. Being made of special hard metal, and of much greater weight than standard pipe, ash conveyor pipe is much more expensive.

Fifth—No Moving Parts. As there are no moving parts to this conveyor, and nothing moves but the ashes, no expert attention by skilled labor is required. No lubrication is necessary.

Sixth—Safety. There is positively no danger of fire, or bin explosion, with the steam jet conveyor as all fire is absolutely quenched by the steam while the ashes are passing through the conveyor. Instances are numerous where red-hot ashes are fed into a conveyor of this type and deposited in wooden bins without ever any occurrence of fire. As there are no moving parts, this is absolutely the best system that can be installed for safeguarding the men employed in the plant.

Seventh—Cleanliness. This conveyor not only does not spill any ashes, but actually removes even the finest dust. When installed in a basement or tunnel, working conditions are improved owing to the changing of air due to the suction in the pipe line.

Eight—No Storage Bin Essential. The operation of this conveyor is not dependent upon the installation of a bin.

FOREIGN RELATIONS

THE LORRAINE IRON AND STEEL INDUSTRY.

The following report of Trade Commissioner J. F. Butler is continued from the May number of THE BLAST FURNACE AND STEEL PLANT in the following: These troubles are said to have been the result of unrest and agitation caused by German elements in the factories. Naturally, at the time of the armistice a large proportion of the workmen were of pure German extraction. Since that period there has been a gradual sifting out of this element, most of them being sent back to Germany. The workmen here, as elsewhere in Alsace and Lorraine, were divided into four classes, as follows: Class A, those of pure French or Alsatian origin; class B, of French-German or Alsatian-German birth; class C, of foreign origin; and class D, of pure German birth. Great restraint has been exercised by the French in sending back to Germany metallurgical workers in class D, the wisdom of such a course being evident when it is considered that a very large proportion of these men were in the highly skilled class and difficult to replace. Persons placed in class D, however, are subject to deportation in case their presence becomes a source of annoyance to the French authorities. This tolerance on the part of the French is said to be partly responsible for a general strike of the metallurgical workers during part of September and October last, resulting in an almost complete cessation of production. Measures have been taken to avert a recurrence of labor troubles, and there is now little fear on this score. In the Forges et Acieries de Hagondange at the present time about 68.5 per cent of the workers are listed in class A, 5.6 per cent in class B, 14.4 per cent in class C, and 11.5 per cent in class D. Work in the steel plants is divided into three shifts of eight hours each. Consideration is being given to the employment of a considerable amount of foreign labor, in order to bring the production up to the pre-war standard. The total number of workers at present is about 22,000.

Present Condition of Plants—Output—Fuel Difficulties.

When the French took over the plants many were found to be in a run-down state, due to intensive exploitation and lack of upkeep during the latter period of the war. In many cases damage was deliberately done to the machinery by the Germans. During the past year a very large part of this damage has been repaired, and the majority of the plants are in very fair condition.

At the present time the Lorraine plants are turning out only about one-third of their pre-war production. This is due principally to the lack of coke for the blast furnaces. Before the war France consumed about 12,500,000 tons of coke, of which it produced only about 6,200,000 tons. The resulting deficit is augmented to the extent of 4,900,000 tons by the annexation of Lorraine, of which the production is slight, making a total deficit of 11,100,000 tons. It is true that the French acquisition of the Saar opens to them rich sources of coal supplies. Unfortunately, the coke produced from this coal is of such a friable nature that it can be used only in small or very medium-sized blast furnaces, being quite unsuitable for the large blast furnaces of Lorraine. Coke could be imported from England, but the cost of transport renders supplies from this source practically prohibitive. A similar objection applies in a smaller degree to coke from Belgium, which, moreover, is available only in limited quantities and is of inferior quality compared with German coke. The Lorraine blast furnaces must continue, therefore, to find their coke in Germany. By the terms of the armistice Germany was supposed to furnish France 11,000 tons of coke daily. This contract was not adhered to, the Germans alleging various reasons for the non-delivery of

coke in the stipulated quantities, especially strikes in the Westphalian coal regions and lack of transports. On May 7 an agreement was reached whereby Germany was to receive $1\frac{1}{4}$ tons of iron ore for each ton of coke sent to Lorraine, Luxemburg, Saar, or Meurthe-et-Moselle. Germany should now furnish France with coke to the extent of 13,000 tons a day. Although the amounts received during the latter part of 1919 were far greater than those of preceding months, they did not exceed one-half the quantity stipulated. This is a source of much embarrassment to the Lorraine industry, which hesitates to contemplate a future of entire dependence on Germany for coke.

In this connection it is interesting to note one of the conclusions made in a report on the iron and steel works in Lorraine by a commission appointed by the British Ministry of Munitions. Reference is made in this report to the great desire of the French to free the Lorraine iron and steel industry from dependence on Westphalian coke. According to the report, the French are said to be considering the erection of coke ovens in Lorraine and the importation of Durham coal to mix with their Saar coal. In exchange for the British coal they would ship basic pig iron to Great Britain. As matters stand the report states, the French feel that their steel industry is too greatly at the mercy of Germany.

Transport Difficulties—Need of Steel in Germany.

The existing railway crisis in France also contributes in a large measure to the difficulties experienced by the Lorraine steel plants. Not only is railway transportation lacking for the carrying of coal and coke, but even for the hauling of the finished and partly finished products to centers of consumption in France. It is only by making a special effort that the products of the Lorraine steel mills are made available for the very pressing needs of the devastated regions and other sections of France, where the demands are far greater than the supplies. On the other hand, it is comparatively easy to export via the Rhine, which may account for shipment to England last August of 40,000 tons of iron and 10,000 tons to Italy. This was sold at a time when a keen demand existed in France.

An interesting note, which incidentally illustrates the great lack of iron and steel in Germany, is the fact that one of the former German proprietors of the Forges et Acieries de Hagondange has recently endeavored to enter into negotiations with the French director of this firm for the purchase of an important quantity of iron and steel for shipment to Germany.

Probable Future Output and Export of French Steel.

What effect will the return of Lorraine to France have on the German iron and steel industry? Before the war Germany produced about 19,000,000 tons of iron, requiring approximately 47,000,000 tons of iron ore, which was secured from the following sources: Prussia, 5,400,000 tons; other German States, 2,000,000 tons; Luxemburg, 7,300,000 tons; Lorraine, 21,100,000 tons; imports, 11,400,000 tons. With Lorraine restored to France and the German economic influence on Luxemburg acquired by France, Germany can count on a present production of only 7,400,000 tons of iron ore, unless a more intensified exploitation of the German mines is possible. On the other hand, France, with the mines in the North producing normally, may calculate on a production of approximately 52,600,000 tons, from the following sources: France, 21,700,000 tons; French North Africa, 2,500,000 tons; Lorraine, 21,100,000 tons; Luxemburg, 7,300,000 tons. However in connection with the above statistics, it should be borne in mind that German coke is at present indispensable to the Lorraine blast furnaces, and France must send Lorraine iron ore to Germany in exchange for this coke.

PRODUCTION TOPICS

NOTES ON THE ACID OPEN HEARTH PROCESS.

(Continued from page 324)

If at that point the furnace were suddenly cooled by shutting off the flame, the effect would be a sudden cooling of the slag, while the temperature of steel, protected from radiation of heat by the blanket of slag would be only slightly affected. This thermal change would have the effect on the slag of considerably increasing its affinity for basic oxides. The only supply of these oxides then available would be the traces still retained by the steel, which would therefore to a greater or less degree be absorbed by the slag. On account of the weight of slag in a heat being only about 7 per cent, while the steel makes up about 93 per cent, or 13 times the weight of slag, a trace of oxides in the steel if absorbed by the slag would be quite a noticeable amount.

This, I believe, is the explanation of the change in the composition of the slag, resulting from shutting off oil and air for one hour before tapping. This treatment was first tried more than 17 years ago, since which time it has been in continuous use, especially in the case of carbon and nickel steel for large ingots.

The cooling effect on the steel, although slight compared with that on the slag, is also advantageous in order to lower the temperature for pouring large ingots, as otherwise the high temperature of the steel would make the ingots pull badly in forging. For this reason the steel is still further cooled by holding it from 20 to 30 minutes in the ladle before starting to pour.

This ends the difference in the treatment of acid from that of basic open-hearth steel. I only want to add, that though this treatment is simple enough, it requires great skill and good judgment on part of the men in the shop, and that uniformly good results can be obtained only by careful and intelligent men after many years of training.

SIXTY MILLION TONS IRON ORE MINED IN 1919.

The iron ore mined in the United States in 1919, exclusive of that containing 5 per cent or more of manganese, is estimated to have amounted to 60,466,000 gross tons, a decrease of 13 per cent as compared with 1918. The shipments of ore from the mines in 1919 are estimated at 56,319,000 gross tons, valued at \$203,274,000, a decrease in quantity of nearly 22 per cent and in value of nearly 17 per cent as compared with 1918. The average selling value of the ore per gross ton at the mines for the whole United States in 1919 was \$3.60; in 1918 it was \$3.39. The stocks of iron ore at the mines, mainly in Michigan and Minnesota, apparently increased from 8,471,507 gross tons in 1918 to 12,986,000 tons in 1919, or 53 per cent.

To obtain these statistics preliminary figures received from producers of nearly 97 per cent of the normal output of iron ore were compiled by Hubert W. Davis, of the United States Geological Survey, Department of the Interior, and were supplemented by estimates covering the remainder of the output.

Although the iron-mining industry itself experienced little labor trouble during 1919, production and shipments were hindered by the closing down of blast furnaces brought about by the steel and coal strikes. Shipments at upper lake ports were also delayed for a short time on account of the strike of ore handlers.

The results of the estimate are sufficiently complete to show totals for the principal iron ore producing states, and by grouping together certain of these states the totals for

the Lake Superior district and for certain other geographic units are obtained.

Lake Superior District.

About 86 per cent of the iron ore mined and shipped in 1919 came from the Lake Superior district, in which 52,126,000 gross tons was mined and 48,463,000 tons was shipped, decreases of 13 and 22 per cent, respectively, as compared with 1918. The ore shipped in 1919 was valued at \$179,485,000, a decrease of about 16 per cent. The mines in Minnesota furnished 71 per cent of the total iron ore shipped from the Lake Superior district in 1919 and 61 per cent of the total of the United States. The average selling price of the ore at the mines in the Lake Superior district in 1919 was \$3.70 a ton; in 1918 it was \$3.46. The stocks of iron ore in this district apparently increased from 7,856,710 gross tons in 1918 to 11,887,000 tons in 1919, or 51 per cent. The shipments of iron ore by boat from the Lake Superior district in 1919, according to figures compiled by the Lake Superior Iron Ore Association, amounted to 47,177,395 gross tons, a decrease of 23 per cent as compared with 1918.

Southeastern States.

The Southeastern States, which constitute the second largest iron ore producing area, including the Birmingham and Chattanooga districts, mined 5,740,000 gross tons of iron ore in 1919, a decrease of 17 per cent as compared with 1918. The shipments of ore to blast furnaces from these States in 1919 amounted to 5,550,000 gross tons, valued at \$15,914,000, a decrease in quantity of 25 per cent and in value of nearly 18 per cent as compared with the previous year. The average selling value of the ore in these states in 1919 was \$2.87 a ton; in 1918 it was \$2.65.

Northeastern States.

The Northeastern States—New Jersey, New York, and Pennsylvania—mined 1,814,000 gross tons of iron ore in 1919, a decrease of 2 per cent, and shipped 1,522,000 gross tons, a decrease of 15 per cent. The average selling value of the ore in these states in 1919 was \$4.06 a ton; in 1918 it was \$4.87.

Western and Other States.

Colorado, New Mexico, Utah, and Wyoming, the principal iron ore producing states, in the West, are estimated to have mined and shipped 655,000 gross tons of iron ore in 1919, a decrease of 16 per cent as compared with 1918. The average selling value of the ore in this group of states in 1919 was \$1.80 a ton; in 1918 it was \$1.74.

Other states, including California, Connecticut, Idaho, Iowa, Maryland, Massachusetts, Missouri, Montana, Nevada, Texas, and Washington, in which there are small iron mining operations, are estimated to have mined 131,000 gross tons of iron ore in 1919, a decrease of 3 per cent as compared with 1918. The shipments from mines in these states in 1919 are estimated at 129,000 gross tons, an increase of 1 per cent. The estimated average selling value of the ore from these states in 1919 was \$3.99 a ton; in 1918 it was \$3.97.

Imports and Exports.

The imports of iron ore for the 11 months ending November 30, 1919, amounted to 423,507 gross tons, valued at \$2,192,619 or \$5.18 a ton. The imports for the year 1918 were 787,468 gross tons, valued at \$3,464,304, or \$4.40 a ton. The exports of iron ore for the 11 months ending November 30, 1919, amounted to 995,577 gross tons, valued at \$4,302,734, or \$4.32 a ton, compared with exports for the entire year 1918 of 1,256,383 tons, valued at \$5,535,090, or \$4.41 a ton. The statistics of imports and exports were compiled from the records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.



Clyde E. Dickey, president of the Clyde E. Dickey, Inc., New York, has been elected first vice president and general manager of the Hammond Steel Company, Inc., Syracuse, New York.

✓ ✓

William T. Lewis, formerly hot mill foreman of the Farrell, Pa., plant of the American Sheet & Tin Plate Co., has been appointed superintendent of mills of the Liberty Works of the Trumbull Steel Company, near Leavittsburg, O.

✓ ✓

Chester A. Orr, formerly superintendent of the Central blast furnace plant of the American Steel & Wire Co., Cleveland, O., has been elected vice president of the Cromwell Steel Company, Lorain, O.

✓ ✓

Robert H. Watson has resigned as general superintendent of the blast furnaces of the Detroit Iron & Steel Co., Detroit, Mich., to become superintendent of the new blast furnaces of the Ford Motor Company, Detroit.

✓ ✓

A. V. Rigby, formerly master mechanic at the North works at Farrell, of the Carnegie Steel Company, has been appointed assistant general superintendent at the Sharon and Farrell works.

✓ ✓

D. T. Haddock, who for the past three years was superintendent of the Farrell, Pa., plant of the American Steel & Tin Plate Co., has resigned after being in the employ of that company for 20 years. He was formerly located at Demmler, Pa., and afterwards at the Farrell plant of the same company.

✓ ✓

George A. Lamb has been appointed superintendent of the plant of the Sligo Iron & Steel Co., Connellsville, Pa., after having resigned a similar position with the American Car & Foundry Co.

✓ ✓

E. L. Ramsey has resigned as open hearth superintendent of the American Steel Foundry plant at Alliance, O., to become superintendent of the open hearth steel plant of the Eastern Steel Company at Pottsville, Pa.

✓ ✓

Charles Davis has been appointed assistant superintendent of the Youngstown Sheet & Tube Co., Youngstown, O., succeeding Fred Lawrence, resigned. Mr. Davis was formerly a roller at the above named company.

Taylor Allderdice, vice president in charge of operations National Tube Company, Pittsburgh, has resigned to become a member of the Pittsburgh Board of Public Education.

✓ ✓

William H. Kochenderfer, Philadelphia, formerly employed in the Southwark Foundry Company plant, has been sent to Chambersburg Foundry & Machine Co., Chambersburg, Pa., by that company as general manager.

✓ ✓

Thomas O'Brien, district manager of the American Sheet & Tin Plate Co., at Ellwood, Ind., has been promoted to the management of the Farrell works at Sharon, Pa., of that company.

✓ ✓

J. C. Williams, vice president and general manager of the Weirton Steel Company, Weirton, W. Va., has returned to his duties from a vacation spent in England.

✓ ✓

W. C. Rott, formerly connected with several large steel companies, has joined the staff of Barton R. Shover, consulting electrical iron and steel plant and steam engineer, Oliver Building, Pittsburgh.

✓ ✓

George Pipoly has resigned from the industrial relations department of the Youngstown Sheet & Tube Co., Youngstown, O., to engage in business.

✓ ✓

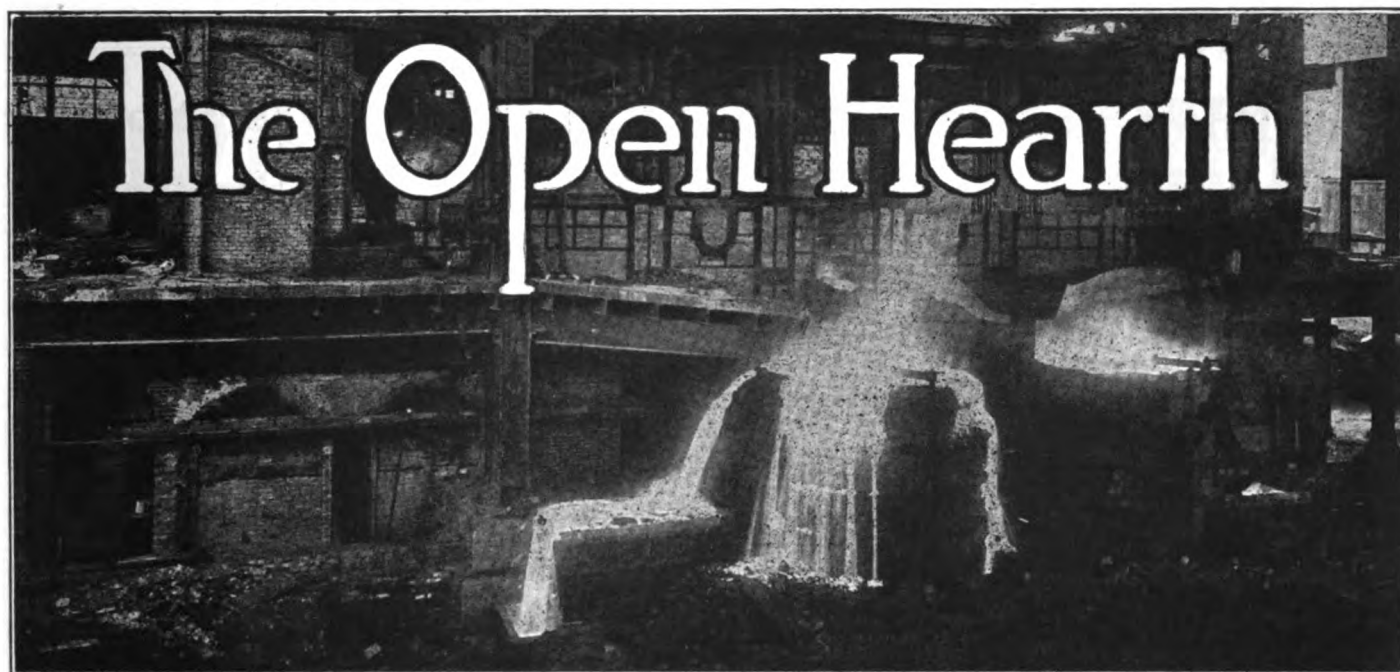
W. H. Warren, formerly general manager of the Brier Hill Steel Company, Youngstown, O., will spend several months on a trip to California and other western points.

✓ ✓

Dwight E. Clark has been appointed superintendent of the Farmer Iron Works, New Haven, Conn. Mr. Clark was formerly foreman with the Worcester Ornamental Iron Works, Worcester, Mass.

✓ ✓

H. A. Baxter, metallurgical engineer of the Tacony Steel Company, has been appointed metallurgical engineer of the Penn Seaboard Steel Corporation. Mr. Baxter is a graduate of the Chemical Engineering course of the University of Michigan (B. Sc '09). After two years as metallurgical engineer for the H. H. Franklin Automobile Company, Syracuse, Mr. Baxter became associated with the Midvale Steel Company, Philadel-



phia, as sales manager. In 1915, he was made assistant superintendent of Midvale's ordnance treatment department and subsequently was appointed superintendent of this department. In the fall of 1917, he resigned from Midvale to become the metallurgical engineer of the Tacony Ordnance Corporation, which in August, 1919, following the successful completion of large ordnance contracts for the United States government, consolidated with the Tacony Steel Company. Mr. Baxter is a member of the Iron and Steel Institute of London, the American Society for Testing Materials, the American Institute of Metallurgical and Mining Engineers, the Society of Automotive Engineers, the American Society of Steel Treating and the Army Ordnance Association.

✓ ✓

It was incorrectly stated in the May issue of THE BLAST FURNACE AND STEEL PLANT that Harry C. Davis, formerly superintendent of the Thomas and Empire hot mills of the Brier Hill Steel Company, would be operating manager of the new sheet mills to be erected at Ashtabula, O., by the Ashtabula Steel Company. Mr. Davis will not be associated with this company.

✓ ✓

I. Lamont Hughes who has been ill for sometime, has resumed his duties as general superintendent of the Carnegie Steel Company at Youngstown, O.

✓ ✓

A. D. Hirsth has accepted the position with Perin and Marshall, consulting engineers, New York, and will soon leave for India, where he will have charge of the construction of two blast furnaces for the Tata Iron & Steel Co., near Calcutta. Mr. Hirsth was formerly with the Brier Hill Steel Company, Youngstown, O.

✓ ✓

Brent Wiley, manager steel mill section, industrial department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, has been appointed assistant to manager, industrial department, in charge of mill industries. Mr. Wiley, after graduating from the Rose Polytechnic Institute, Terre Haute, Ind., in 1898, entered the electric department of the Ohio works, Carnegie Steel Company, where he stayed one year, and was then transferred to the Homestead works of the company as assistant to the electrical engineer. For two years, Mr. Wiley was electrical engineer for the Wellman-Seaver-Morgan Company, Cleveland. In 1906 he became as-

sociated with the Westinghouse company as commercial engineer, engaged in steel mill work, industrial and power department. Mr. Wiley was appointed manager of the steel mill section in 1909, which position he has held until his recent appointment. He is a member of the Iron and Steel Institute, Association of Iron and Steel Electrical Engineers, American Electrochemical Society, Electric Furnace Association and the Engineers' Society of Western Pennsylvania.

✓ ✓

A. Schmidt has been appointed vice president and general manager of the Federal Iron Works, Youngstown, O. Mr. Schmidt was formerly manager of the Lau Iron Works, at Youngstown, O.

✓ ✓

F. William Richards has recently resigned as works manager of the Columbia Malleable Castings Company, Columbia, Pa.

✓ ✓

Thomas J. Gillespie, who recently was elected president of the Lockhart Iron & Steel Co., Pittsburgh, has been identified with that company since its organization in 1890. His election to the position of head of the company merely is a change of titles, as Mr. Gillespie has been secretary and treasurer, general manager and chief executive of the company during the 30 years of its existence. Mr. Gillespie has found time for numerous philanthropic and charitable movements. He has been a member of the state executive committee of that body and of its national advisory committee.

✓ ✓

W. C. Coryell, formerly connected with the Carnegie Steel Company at Youngstown, O., has been appointed chief engineer of the General Fire-Proofing Company, Youngstown, O.

✓ ✓

Charles E. Duncan has been appointed general superintendent of the Algoma Steel Company, Sault Ste Marie, Ont. Mr. Duncan recently resigned from the Mesta Machine Company, Pittsburgh.

✓ ✓

Guy D. Leopold has resigned as purchasing agent and traffic manager of the Edgewater Steel Company, Pittsburgh, to accept a similar position with the Austin Company, Cleveland. Mr. Leopold will be succeeded by Walter McKean, formerly with the Westinghouse Electric & Manufacturing Co.

Some Pointers on By-Product Coke Oven Operations

BY-PRODUCT COKE OVEN DEVELOPMENTS.

(Continued from page 337.)

Terre Haute, Ind. These ovens have an average width of 16 inches, being adapted to coke Illinois and Indiana coal. They are the ordinary Koppers cross-regenerative coke ovens heated with coke oven gas. The performance of these ovens has been very satisfactory, and the heating regulation is so good that there are no indications that the maximum height possible with ordinary coke oven gas heating has been reached.

New Developments Facilitating Use of Higher Ovens.

Whatever this limit may be, and whether or not it ever will be reached in actual construction, it is gratifying to know that our resources for uniform heating over great flue heights are by no means confined to the limitations imposed by straight coke oven gas firing. With producer gas firing, it is possible to get uniform heat distribution through a great height of flue, but we may, with ordinary coke oven gas, obtain the same degree of uniformity through flues of great height by the system of waste gas return that has been developed by The Koppers Company. Thus, we have three important accomplishments contributing to new possibilities in the way of increase of oven height and consequent increase of unit coking capacity, viz.:

1. The development of a wall construction of maximum strength and efficiency as accomplished in the triangular flued system.
2. The successful application of producer gas to oven heating.
3. The development of the waste gas return system.

The Waste Gas Return System.

This system has been applied in a simple and most ingenious manner by utilizing essentially the structure already provided in the cross regenerative combination oven. When the ovens are fired with coke oven gas, the regenerators are all used for air as usual. When producer gas is used, the coke oven gas distributing flue is idle and every alternate set of regenerators throughout the battery is used for preheating the producer gas, while every other alternate set is used for preheating the air. Now, in the system of waste gas return, it is designed to use coke oven gas for heating the ovens; but it is also designed so to introduce waste inert products of combustion into each burning flame-flue, that the coke oven gas flame will practically have the distended character of a producer gas flame. To this end, waste gas is cooled and conveyed from the stack flue into alternate regenerators of the combination oven, while the other alternate regenerators are employed for air, as in producer gas operation. These returned waste gas regenerators feed the reheated waste gas directly into the same flame-flues that are being directly fed with air from the air regenerators and with coke oven gas from the coke oven gas distributing flue, and the quantity and velocity of such returned waste gas food is completely regulable. The operations of reversing take place at the usual intervals. With such a system, it is possible to obtain an equally satisfactory degree of temperature uniformity throughout a great height of flue as when using producer gas, and it is obvious that a plant of combination ovens equipped with both waste gas return and producer gas systems in an apparatus of great

flexibility with respect to coke and gas production.

Such flexibility is of even greater importance in the artificial gas industry than in iron and steel plants and, so far, the application of the waste gas return system has been designed primarily with reference to gas ovens, although it has important developments in connection with coke oven plants as well.

The New Koppers Gas Oven.

The foregoing consideration all naturally lead up to the new Koppers gas oven—a development which is considered very important for the gas industry. This oven can be built at low cost and can be operated at a lower cost than any other adequate apparatus yet designed for the production of coal gas. It is triangular flued, combination, cross-regenerative oven utilizing the Koppers heating principle and can be operated either with producer gas, or with coke oven gas with waste gas return, or with straight coke oven gas. It combines the advantages that have been enumerated as relating to the triangular flued construction, producer gas firing, and the waste gas return system. It has the maximum of flexibility with respect to gas output. An extended discussion of this new gas oven would be unsuitable for the purpose of this paper, but it is intended within the near future to publish an article dealing exclusively with this subject for the benefit of those who are especially interested. A few of the salient features will merely be mentioned here.

A sectional drawing of the flues, regenerators and gas distributing systems of the gas oven is shown in Fig. 10. A distinctive feature is that the gas mains and stack flues are all on one side of the battery, which is important from the standpoint of cost and economy of operation. The upper main shown in circular section just outside the oven structure is for the coal gas supply. There are two coal gas distributing flues, the upper communicating with the nozzles on the half nearest to the gas mains, while the lower flue communicates with the nozzles on the far half of the wall. There are two lower gas supply mains shown in U-section. One of these is for producer gas and the other for returned waste gas. The waste gas outlets at the bottoms of the regenerators are positioned so that the passages from the regenerators on the far side of the battery pass along the bottom of the regenerators on the near side and communicate with the stack flue. Alternate regenerators serve for air and for producer gas, or as the case may be, for air and for returned waste gas. Thus, all of the fuel gas and returned waste gas inlets as well as all of the waste gas outlets are brought together on the same side of the battery—an accomplishment which greatly favors convenience of operation. Fig. 11 is a perspective drawing of a typical small plant of these gas ovens, in which certain of the features of oven construction may be more clearly seen than in the diagrammatic drawing.

The oven is designed to have a capacity of 7.6 net tons of coal and is of such width as to operate on 12 hours coking time with a daily capacity of 15.2 net tons coal producing 160,000 cubic feet of gas.

The possibility of operating such ovens at 12 hours coking time has interesting application in reducing operating costs. A plant having ample gas storage capacity can be operated with two eight-hour shifts, only the heaters and producer operators being required on the third shift.

NEWS OF THE PLANTS

The Eastern Rolling Mill Company, Baltimore, has inaugurated operations at its new works on Baltimore street, which have been in course of erection for some months past. Initial production will be concentrated at six hot mills, intermediate and finishing departments, and it is planned to place the other unit of six hot mills in service during June. The present output will average about 60,000 tons of steel per year and it is proposed to increase this production at an early date. The expansion plans include a duplication of the present works; the company has a site of about 25 acres of land and has taken options on 25 acres of adjoining property for its proposed extensions. The initial plant covers an area of about 375x1,000 feet, and will give employment to about 1,200 men. The production will be devoted for the most part to high grade steel sheets for automobile body manufacture and other purposes. The company will operate with a capital of \$5,000,000. J. M. Jones is president and plant manager.

The Milliken Brothers Manufacturing Company, Woolworth Building, New York, manufacturer of standardized structural steel buildings, transmission towers, radio towers, and steel poles, is concentrating operations at the present time on its industrial buildings, known as Milliken Buildings. Contracts secured up to the present time, both for domestic and foreign shipments, insure maximum operations for some months to come. The material for these structures is pre-fabricated, and the buildings are provided with heavy corrugated steel sides and roofs, calling for the best grade of material in this line. To facilitate operations in the field the company has arranged for representation at a number of important centers, including Chicago, Cleveland, New Orleans, Raleigh, N. C.; Dallas and Houston, Tex.; Tulsa, Okla.; in Cuba, M. T. Walsh, Havana, will represent the company, while in Great Britain, the Milliken Brothers Manufacturing Syndicate, Ltd., will handle the business. It is planned to enlarge this representation from time to time.

The Atlas Crucible Steel Company, Dunkirk, N. Y., has arranged financial matters to provide for an active operating capital of \$5,500,000. The company has extensive plans under way for the erection of a number of additions to its plant for increased production, and arrangements have been made with the city for a vacation of certain lands for the new structures. The property is located on Howard street and other thoroughfares. The proposed buildings will include an addition to the annealing works, 70x200 feet; metal melting shop extension, 70x120 feet; new 16 and 28 in. mill buildings, 80x235 feet; addition to wire mill, 40x140 feet; and billet storage extension, 158x170 feet. With the facilities provided in these new structures it is planned to double approximately, the present output. The work is estimated to cost about \$1,000,000, including machinery and equipment. A large increased working force will be arranged for.

The Superior Sheet Metal Company, Canton, O., has arranged for an increase in its capital from \$2,000,000 to \$4,000,000 for proposed expansion. The company is now erecting a sheet mill comprising a number of units and the plant will be increased over the size and output as initially anticipated. A complete jobbing mill will also be constructed

to be used for the production of blue annealed sheets of heavy stock. It is planned to place the initial units of the plant in operation early in July, including from four to five mills, with auxiliary operating buildings.

The Wharton Steel Company, Wharton, N. J., has arranged for the installation of a new sintering works at its local mills. The company has secured permission from the American Ore Reclamation Company, 71 Broadway, New York, to use the Dwight & Lloyd process machines for this work. The installation will consist of two double-length sintering machines, with capacity of about 700 tons of sinter per day from ore concentrates and flue dust. The installation will be made by the Arthur G. McKee Company, Cleveland, O. It is now contemplated to increase the equipment to a total of six machines at a later date.

The St. Louis Coke & Chemical Company, St. Louis, Mo., is making rapid progress in the erection of its new blast furnace and coke ovens at Granite City, Ill., and expects to have the plant ready for initial operations some time in July. The blast furnace will have a capacity of about 500 tons of pig iron per day, and the coke department will comprise a battery of 80 ovens. The pig iron output will be shipped as hot metal for utilization at the plant of the National Enameling & Stamping Co., in this vicinity. The coke plant will have an output of about 1,500 tons of material, and will handle approximately 2,000 tons of Illinois coal per day. A portion of the production of the latter branch of the works will be used at the company's blast furnace.

The Connellsville Electric Steel Company, Connellsville, Pa., has been organized to take over the property and assets of the United States Electric Steel Company, which has been in financial difficulties. The works of the company were secured by officials of the new organization at a recent sale. These comprise a plant on the Youghiogheny river at Connellsville, well equipped for production. It is reported that the new company is planning to inaugurate operations at an early date. Officers of the new organization are G. M. Gadsby, president; F. W. Wright, vice president; R. B. Keating, vice president; G. E. Murrie, secretary, and F. E. Markell, treasurer.

The Sligo Iron & Steel Co., 42 Broadway, New York, has been reorganized with increased capitalization to provide for expansion of its works at Connellsville, Pa. The present plant has a capacity of about 5,000 tons of sheets and merchant bars per month, and it is proposed to increase this to about 7,500 tons. Building of an addition to the sheet mill has been inaugurated, and the various increases in output will be divided among this department, the 16 in. finishing mill, a 9 in. finishing mill, and the muck mill. The initial expansion is estimated to cost about \$60,000, and considerable new equipment will be installed. The company has a site totaling about 16 acres of land in this district, and six acres are now being utilized for plant buildings and operations. W. W. Darley has been elected president to succeed S. C. Munoz; he has formerly acted as vice-president.

INDUSTRIAL RELATIONS

INDUSTRIAL ACCIDENTS AND THEIR PREVENTION

The following is taken from Bulletin No. 47, published by the Federal Board for Vocational Education:

Forms of Safety Organization.

The existing working force of every industrial concern, whether large or small, is adaptable readily to a safety organization. No new employees are required unless it be the case of large concerns in which it might be necessary to select some person to devote himself exclusively to the inspection work. The only differences are that the organization does not need to be so extensive in the small plant and that the duties in such a plant are performed by different factors in the organization.*

The generally accepted plan of inaugurating a safety organization embodies five features:

1. Support of the management.
2. Support of the foremen.
3. Central safety committee.
4. Workmen's safety committee.
5. Safety engineer (or inspector).

Support of the Management.

Experience in the past decade has conclusively proven that the work of accident prevention is not a "one man job;" that satisfactory results can be secured only through the highest measure of coöperation between the employer and his employees, and this only by means of organization. The employer must be vitally interested in the work if he expects to educate his men to share the responsibility with him. The men must be given a part to perform in it, if their interest is to be aroused and maintained. The work must touch them somewhere, and they must be brought into direct relationship with their employer. It is only through organization that this is possible, whether the plant be large or small.

Reaching the Manager.

Safety in a plant must begin at the top. The manager and superintendent must believe in it as a business proposition just as they believe in fire prevention or anything else that prevents waste and increases efficiency. They must give safety a dignified position in the organization, get back of it and stay back of it so unmistakably that every foreman and workman will know what the officers propose to do to make the plant safe, and what they expect the foremen and workmen to do. Without this backing from the manager and superintendent a safety engineer can do little in reaching the workmen and in awakening the real safety spirit.

How to Convince the Manager.

Managers and superintendents do not neglect safety because they are inhuman and indifferent to the welfare of their workmen. It is because they are not informed as to what has been accomplished in accident prevention, and they do not know that safety pays good dividends on the investment.

If a manager and superintendent are not interested in accident prevention, or if they do not give the necessary support, the first duty of the person responsible for the conduct of the safety work is to convince them by placing before them the experience of other companies that are doing successful safety work. A manager is always interested in what some other company is doing and the savings which

are being made. He must be convinced by hard facts.

It is important that the management has placed before it an outline of the methods used by representative companies in accomplishing their favorable results. Emphasis should be made on the point that from one-half to two-thirds was accomplished through organization and educational methods. In presenting plans for a safety organization, an effort should be made to convince the management that they include standards used successfully in all companies doing the most efficient safety work.

What the Manager and Superintendent Can Do.

In starting a safety campaign, a manager should call a meeting of all foremen and sub-foremen, at which he should preside. He should outline the plan and state what the company proposes to do to make the plant safe, and what the officers expect of every foreman. The manager should seek to convince the foremen of the practicability of the proposed plan by placing before them the experience of other companies. He should emphasize the point that from that time on safety must be recognized as an indispensable part of an efficient department; a foreman's first duty is the protection of his men. At this meeting the manager should announce regular monthly safety meetings of the foremen. He should request each foreman to make a rigid inspection of his department and to submit within a week a written report of all points which should be guarded, indicating those which should be considered first.

The company must first do its part—must convince the workmen by visible signs in the form of mechanical guards—before the foreman can go to the men and ask them to coöperate.

After considerable guard building has been done, and after the manager and superintendent have succeeded in interesting the foremen, then a meeting of all employees should be called. At this meeting the manager and superintendent should speak and should lay before the men the causes of accidents, emphasizing the point that a large percentage can not be prevented by anything which the company can do. They should drive home the fact that the workmen are a thousand times more concerned than the company; they can lose their limbs and their lives—the company only loses money.

The manager should announce the new plans for safety work and should place the company and himself on record as willing to do anything possible to protect the men—if they will do their part.

The superintendent should announce the names of the workmen who are to serve on the workmen's inspection committees and emphasize the importance of their work.

Not only should the manager and superintendent give the safety work their support at the start, but they should actively identify themselves with the movement, so that the foremen and workmen will be constantly reminded of their interest.

The superintendent should attend all foremen's meetings, and act as chairman. The manager should frequently attend and express his deep interest in safety.

*See further "How to Organize for Safety," published by the National Safety Council, Chicago.

†In this paper "manager" means the chief executive in the plant.

WITH THE EQUIPMENT MANUFACTURERS

GRINDING FOR DRESSING OFF GAS AND ARC WELDS.

The Van Dorn Electric Tool Company, of Cleveland, O., has recently developed alternating and direct current aerial grinders, particularly suited for dressing off the overflow metal along the welding line. These two grinders are each suspended on a spring with 12 inch extension and 6"x1"x½" guarded wheel. The dc grinder and 3-phase ac grinder are one-half hp and the single phase ac grinder is one-third hp A. I. E. E. rating.

In all three types the end plate and extension spindle housing are made of steel. In the dc type the motor housing is also steel but in the one-third hp and one-half hp ac types this is constructed of aluminum to keep down the weight. Both types are completely equipped with ball bearings of liberal size to insure running ease and assure that all the power is used in the cutting face of the wheel.

The shaft is locked to the inner races of the ball bearings to provide end thrust and eliminate shaft wear. These tools are adapted for all kinds of light grinding and for dressing off arc welding of window and door sash in passenger car building, polishing, etc.

COMBINATION TOOL FOR MACHINE SHOP.

The Ackland patented screw driver is in reality a combination ratchet, socket wrench, drill and screw driver, combined with a specially designed and powerful lever device for holding the tool to the work.

The production of this patented combination tool by the Ackland Specialty Company, of Springfield, Mass., is a direct result of the world war and the steady growth of the automobile industry. It is in great favor with the automobile repairmen and has become an indispensable part of the equipment of the Government armory, where it is used to remove rusted in and battered bolts, nuts and screws from the used equipment which is being repaired and overhauled since the boys finished "doing their bit" with the machine gun, rifle, etc. The patent covers a verticle member of square cross-section which can be engaged at any point with either a ratchet or ordinary wrench.

LARGEST VERTICAL SCREW POWER TESTING MACHINE IN THE WORLD.

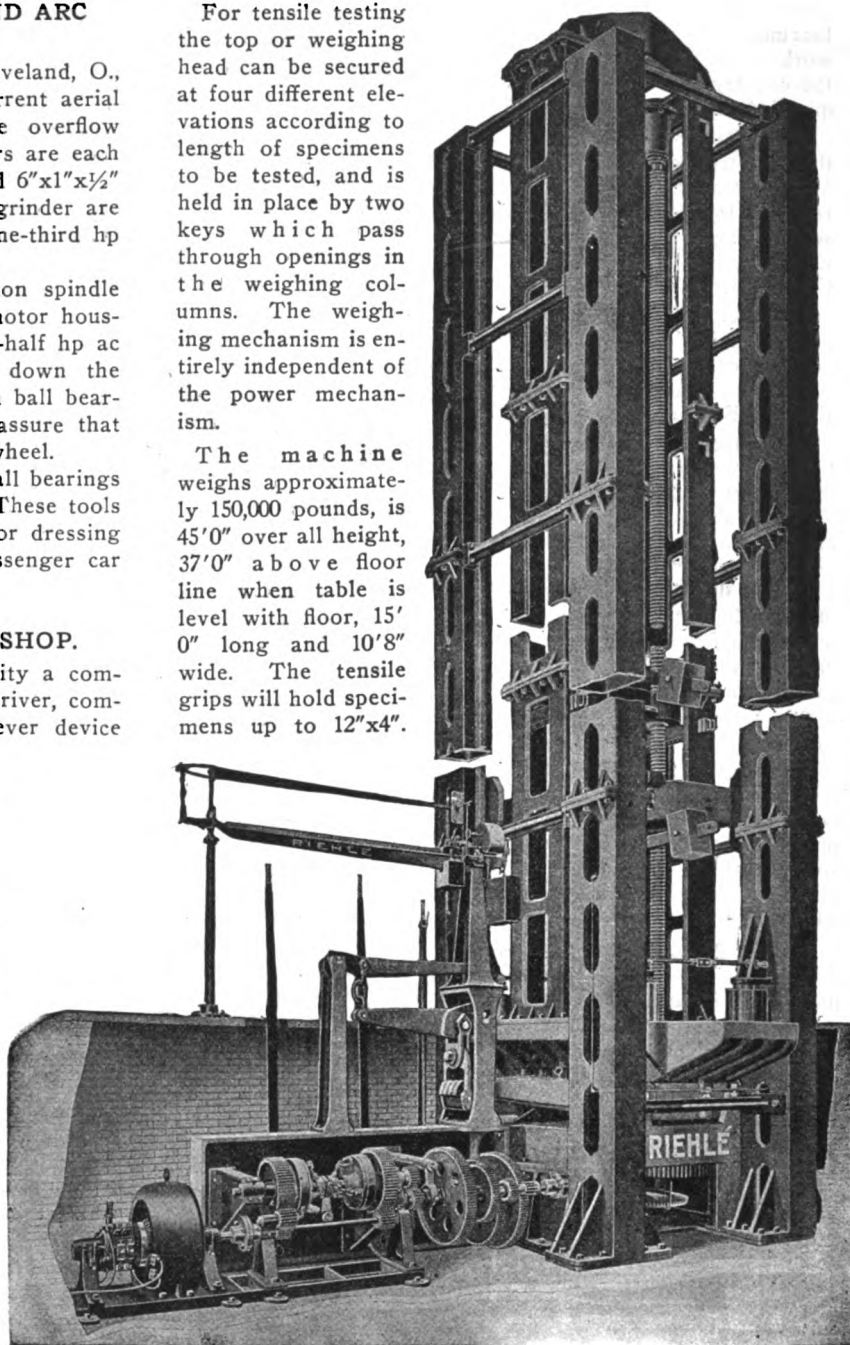
The Riehle Brothers Testing Machine Company, of Philadelphia, has just completed, for the United States Government, the largest vertical screw power testing machine in the world (1,000,000 pounds capacity) to be installed at the Forest Products Laboratory, Madison, Wis.

The machine is of the two-rotating screw type similar to those now in use by the American Steel Foundries, Alliance, O., and the W. H. Miner Company, Chicago, Ill., but having special features not on those machines.

This machine is arranged to test columns 30'0" or less in compression and will take specimens 10'0" long or less in transverse. When arranged for tensile specimens the maximum travel of the pulling head is approximately 29'0".

For tensile testing the top or weighing head can be secured at four different elevations according to length of specimens to be tested, and is held in place by two keys which pass through openings in the weighing columns. The weighing mechanism is entirely independent of the power mechanism.

The machine weighs approximately 150,000 pounds, is 45'0" over all height, 37'0" above floor line when table is level with floor, 15'0" long and 10'8" wide. The tensile grips will hold specimens up to 12"x4".



One million pound testing machine.

The weighing beam is of the micrometer dial screw type; the dial is graduated by 100 pound marks to 10,000 pounds, and the beam readings are by 10,000 pounds to 1,000,000 pounds. A needle beam is provided to magnify the swing of the weighing beam. A one-tenth poise is also furnished to be used for light loads.

The machine has four speeds, 10 inch per minute for adjusting the pulling head and pulling speeds of 2 inch, ½ inch, 1/10 inch per minute.

TRADE NOTES

D. Gleisen, manager industrial bearings division, Hyatt Roller Bearing Company, has appointed W. F. Myer to be directing transmission engineer, effective at once. In his new position Mr. Myer will be responsible for the sale of Hyatt line shaft roller bearings, and as he has been doing field work with the Hyatt agents throughout the country for over two years, he is well qualified to effectively handle this work.

N. N. Baad, who formerly had charge of the heat treating department at the De La Vergne Machine Company of New York, resigned to accept a position as sales and service engineer with the F. A. Calhoun Company, 76 Montgomery street, Jersey City, N. J.

The Electric Furnace Construction Company, Finance Building, Philadelphia, reports repeat order for a 1½ ton "Greaves-Etchells" furnace for Charles Bertolus, St. Etienne, France.

Announcement is made of the consolidation of the executive and sales offices of the Booth Electric Furnace Company, Chicago, at the same address as the engineering and production office, which has been located at 326 West Madison street. Effective May 1 the address of the general office of the company will be at this address, where adequate office space and facilities have been secured to take care of all departments.

The Iron Age Publishing Company has just published the Iron Age Catalogue of American Exports, for distribution in the civilized countries of the world. It contains the catalogues of leading American manufacturers of engineering railway, foundry and electric equipment and supplies, iron and steel, machinery and tools, hardware and cutlery.

George R. Brandon, formerly engaged in engineering and sales of foundry equipment and cranes, has recently been appointed district representative and sales engineer by the General Construction Company, Chicago, Ill., manufacturers of "Oil-gas" furnaces for all industrial purposes. His headquarters will be 342 Monadnock Building, Chicago.

Ernest H. Peabody, for many years employed by the Babcock and Wilcox Company, as engineer, salesman, and in a general executive capacity, has recently resigned his position to become president of the Peabody Engineering Corporation, with general offices at No. 160 Broadway, New York City. This company was incorporated under the laws of the state of New York about the first of February, 1920, and will undertake the furnishing of oil burning equipment of all kinds, including mechanical atomizing burners, steam atomizers and burners for industrial furnaces. Mr. Peabody's broad experience in combustion engineering, both in the marine and stationary field, and particularly in the use of oil as fuel, and the opportunity he has had for the exhaustive study of conditions

leading to the best economic results, fits him especially for the work which he is now undertaking.

L. H. Keim has been appointed general sales manager of the R. D. Nuttall Company, gear manufacturers, of Pittsburgh, Pa. Mr. Keim came with the company in 1911 as engineer in charge of erection work and the installation of equipment. One year later he was promoted to the position of assistant chief engineer, designing and developing heavy duty railway and steel mill gearing. In 1916 he developed a standard tractor transmission unit and was soon placed in complete charge of this new field. His headquarters were in Chicago, Ill., from where he extended service to gear users of every class. From this work Mr. Keim has been brought back to the main office at Pittsburgh, to take charge of his present duties.

The Schaffer Engineering & Equipment Co., to provide for the expansion of their business and to obtain ample plant facilities, has sold a large block of its capital stock to the Fawcus Machine Company. The Schaffer company's processes, engineering achievements and line of machinery, including poidometers, hydrators, coal injectors and screens need no further comment at this time. The rapid growth of their business necessitated better manufacturing facilities and assistance in handling the natural growth of this business. The Fawcus Machine Company, manufacturers of gears and special types of machinery, with large plants at Pittsburgh and Ford City, Pa., will build all machinery required, and the inventive genius of J. C. Schaffer and the thorough understanding of their customers' needs by Waller Crow will be backed by the active interest which the officials of the Fawcus Machine Company will take in the Schaffer Company. The officers of the Fawcus company, who will take active interest in the Schaffer organization, are A. F. Cooke whose advanced interest in machine shop practice and production has placed him in the foremost ranks; Eliot A. Kebler, prominent in financial circles and actively identified with iron manufacturing companies for many years; and A. A. Alles, Jr., who has done much toward unifying and stabilizing costs in the largest groups of manufacturers. The new officers and directors of the Schaffer Engineering & Equipment Co. are A. F. Cooke, president and general manager; J. C. Schaffer, vice president; Eliot A. Kebler, vice president; A. A. Alles, Jr., treasurer, and Waller Crow, secretary.

The Wellman-Seaver-Morgan Company, Cleveland, O., has recently issued a series of bulletins showing some of the notable installations made by that company. The different bulletins are devoted to the various fields of the company's activities, namely: Bulletin 41, Coal and Ore Handling Machinery; Bulletin 42, Special Cranes; Bulletin 43, Hydraulic Turbines; Bulletin 44, Hoisting and Mining Machinery; Bulletin 45, Steel Works Equipment; Bulletin 46, Coke Oven Machinery; Bulletin 47, Port and Terminal Equipment; Bulletin

tin 48, Rubber Machinery. The scheme of each of these bulletins is to show, on fac-

The American Metallurgical Corporation, Franklin Trust Building, Philadelphia, announce the closing of a contract with the Thermoid Rubber Company, Trenton, N. J., for the installation of electric oven equipment to take care of the production of a special processed product to be placed on the market by this company.

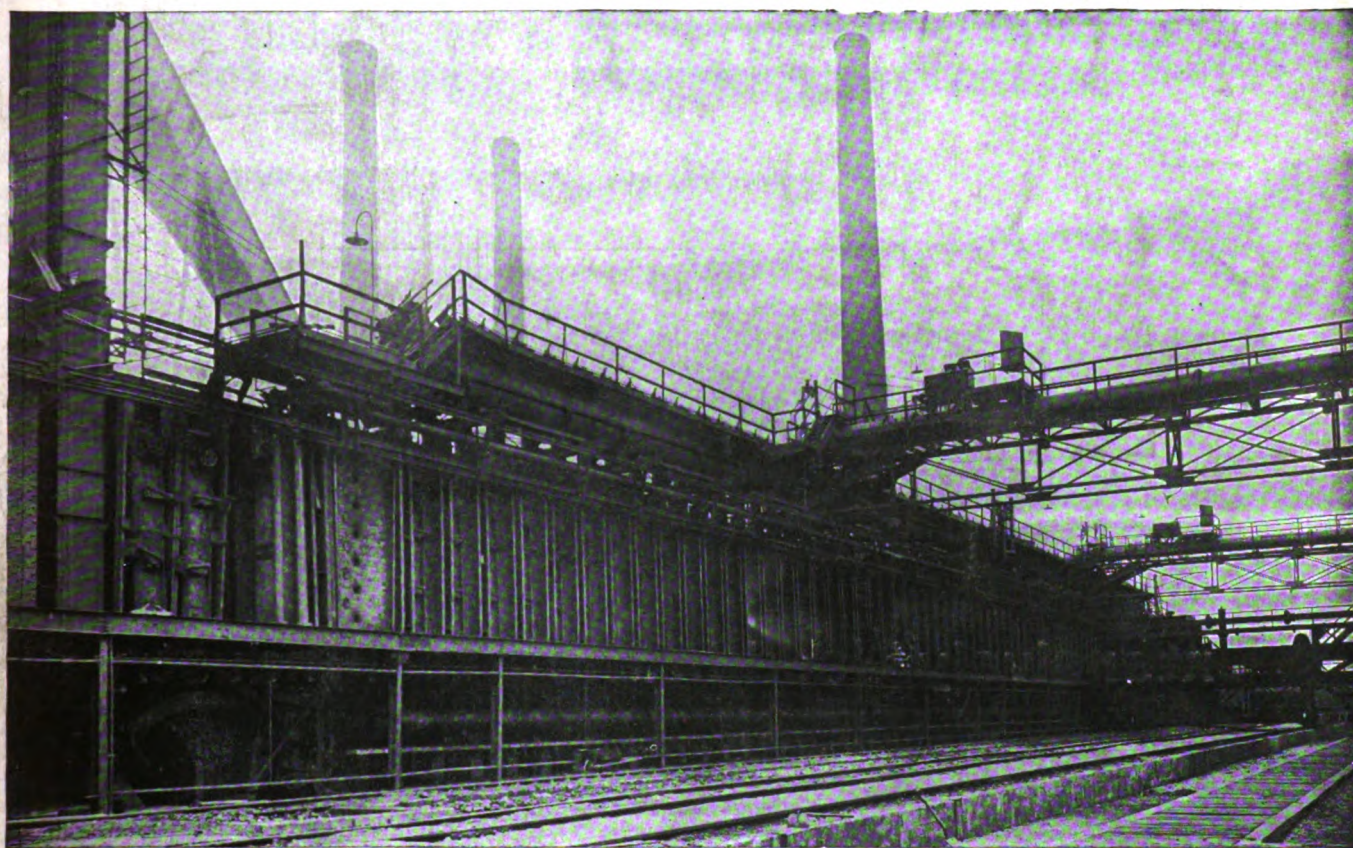
W. C. Buell, Jr., formerly engineer of tests, and later chief engineer of Tate-Jones & Co., Inc., on June 1, became associated with the George J. Hagan Company, of Pittsburgh, furnace and combustion engineers, as chief engineer of their newly organized liquid fuel department.

The Cambria Steel Company has authorized extensive improvements at its Johnstown, Pa., plant, involving the expenditure of about \$42,000,000, as announced by L. R. Custer, vice president of the company, in the "Johnstown Democrat" of May 22. The Semet-Solvay Company has been awarded the contract for installing a considerable part of the contemplated improvements, and will carry out a comprehensive plan for the reconstruction of, and addition to the coke oven plant and by-product recovery apparatus. The Cambria Steel Company built at its Franklin plant, the first installation of by-product coke ovens in America, except the original plant of Semet-Solvay ovens at Syracuse, and this Franklin plant now consists of a total of 492 ovens in 11 blocks, consisting of five blocks of Otto-Hoffman ovens, two blocks of Koppers, and four blocks of Cambria, an improvement on the original Otto-Hoffman type. The Semet-Solvay Company will construct a complete by-product plant for the recovery of ammonium sulphate, tar and light oil from these 11 blocks, also a plant for the rectification of the light oil to motor benzol, with a capacity to handle all the light oil produced from both the Franklin plant and the Rosedale plant mentioned below. This work will also include a boiler plant, storage and shipping facilities for all products, and a complete new system of gas delivery and circulation piping for the oven blocks. At the Rosedale plant of the Cambria Company, the Semet-Solvay Company will construct two blocks of Semet-Solvay ovens of 44 ovens each, and will erect an additional block of ovens of the Cambria type from material already on hand, making when completed, a plant of 208 ovens. It will also install a coal washery plant, coal breaker, boiler plant, coal and coke handling machinery, and all equipment necessary for the recovery of ammonium sulphate, tar, gas and light oil, from the four blocks of ovens. When this work is completed, the Cambria Steel Company will have a daily capacity for coking of about 9,000 net tons of coal per day at the two plants.

The Electric Controller and Manufacturing Company, of Cleveland, O., has recently opened a branch office at 49 Federal street, Boston, Mass. The office is in charge of M. D. Goodman.

The Blast Furnace *and* Steel Plant

Pittsburgh, June, 1920.



Battery of 60 Triangular Flued Cross Regenerative Combination
Ovens built by the Koppers Company for the Jones & Laughlin
Steel Co., Pittsburgh, Pa.

KOPPERS

BY-PRODUCT COKE PLANTS
TAR DISTILLING PLANTS

AMMONIA RECOVERY APPARATUS
BY-PRODUCT GAS PRODUCERS

MOTOR FUEL RECOVERY PLANTS

THE KOPPERS COMPANY

Pittsburgh, Pa.